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PRESIDENT'S MESSAGE

Frank F. Groseclose

It's Your Journal

That's right. It *is* your JOURNAL. Your own Professional publication. It's the only one of its kind. Its main purpose is to serve you as the Professional publication for Industrial Engineering. It has grown, and will continue to grow—but only with your help.

The January issue of the JOURNAL OF INDUSTRIAL ENGINEERING marked a happy achievement for AIIE. Starting with this issue the JOURNAL was changed from a quarterly to a bi-monthly publication. This was done to better serve the membership of AIIE, and represents the results of continued work by many individuals. The development of the JOURNAL has been guided by only one principle—to provide service by means of a Professional Industrial Engineering publication. The contents of each issue are selected on this same basis. The various articles are selected to provide as balanced a coverage of the field as possible, with great preference given to original and creative works. Some articles are based on speeches presented to Chapter meetings, some are submitted by the writers when seeking a desirable outlet for their manuscripts, and some are written specifically at the request of the editors as they attempt to balance the issue coverage.

The JOURNAL has grown in circulation as well as in size and frequency of publication. Many company libraries, public libraries, school libraries and individuals subscribe to the JOURNAL. It is very pleasing to note that subscriptions have been entered from all sections of the United States, and from many foreign countries. We hope that this growth will continue.

The JOURNAL is financed by the

(Continued on page 21)

Those Annoying "Human Factors"

By Dr. Kenneth C. Wagner

Industrial Sociologist, Georgia Institute of Technology

The importance of the "human factor" in industry has been widely discussed since the preliminary findings of the famous "Hawthorne" study were published 20 years ago. The excellent definition of industrial engineering set forth by Dr. Lehrer in his January "Editorial Comments" explicitly recognizes the need of considering such a factor in engineering.

But how much have we learned about the human factor in industry? Exactly what are some of these non-engineering factors affecting production and costs?

"The Achilles Heel of Industrial Engineering" in the January *Journal* presented a provocative discussion of the way in which the "practical application" of techniques is neglected in the engineering curriculum. In effect Mr. Denham was saying that schools of engineering are neglecting the human factor because they are—quite understandably—preoccupied with techniques. Yet as he points out, in attempting to apply the techniques he learns the industrial engineer inevitably runs into human problems.

Explicit recognition of a need does not, of course, solve a problem. Some of the implications of the problem Mr. Denham pointed up were revealed by a recent survey of graduates of Georgia Tech's School of Industrial Engineering. They reported spending more time in methods and standards work than in any other area. At the same time, a typical motion and time study text devotes a chapter of less than three pages to the human factor—to the problems that may be encountered in applying motion and time study techniques.

A frank appraisal of the situation produces one conclusion: that the human factor is still a badly neglected step-child. In many ways social scientists are to blame. Until recently few had attempted to apply their concepts and methodology to industrial research. Engineers have likewise been preoccupied with their more immediate problems. Only within the last few years has there been an attempt to coordinate the two perspectives.

In many ways the industrial engineer's immediate need is for a concise "handbook" of principle of human behavior. Included should be the findings of anthropological, psychological, social psychological and sociological research. Unfortunately, none exists. This is not to say that if it were available such an outline would solve all the engineer's human problems. Many such problems develop over a period of months and years, and require intensive research by specialists. An engineer could not expect to have his recommendations for changes accepted readily by a union which for years has been locked in battle with company executives. In such a situation his work might be relatively useless as long as such a conflict existed.

In many cases, however, knowledge of a few basic principles would make it possible to avoid trouble. A study made in a commercial printing plant where the author was formerly assistant production manager provides a good example. Work in this department included the trimming, folding, gathering and packaging of printed material. Stapling, punching and other special operations had long been a bottleneck. Jobs rushed through the composing and press rooms frequently failed to meet shipping deadlines because they bogged down in the bindery. No set routes existed for the processing of different types of jobs. Lifts of paper frequently clogged the aisles, making traffic slow and precarious.

Sweeping changes were recommended by the industrial engineer called in to remedy the situation. The layout of heavy machinery and work tables was completely revamped. A second outside door was cut to permit materials to flow smoothly from press room to loading platform, eliminating a tortuous and erratic routing system. Both the plant manager and foreman approved the proposed changes, which were completed as quickly as possible.

There was only one problem: the women working in the department didn't like the new arrangement. They complained because the tables were now along the walls, rather than nearer the center of the room. They griped because they had to "stay put." Formerly they had to move around to get materials—and in the process they could chat with other employees.

The result was a $1,000 headache. Complaints mushroomed; production dropped. To get production back even to "normal" it eventually was necessary to go part way back to the old layout. The final arrangement was an improvement over the old, but it was still much less efficient than the engineered changes would have been.

Logic—But Not Science

Why didn't the engineer involved anticipate the problems which developed? It is apparent that he had no tools for doing so. His design took only non-human factors into consideration. It was a strictly "logical" design—and in omitting the human factor as a variable it was not scientific.

What we frequently forget is that logic, thoroughness and hard work are no insurance that results will be either scientifically correct or capable of solving a practical problem. False assumptions or the omission of a single variable can render the most logical scheme worthless.

An important and obvious omission made in the bindery change was the engineer's neglecting to learn the background of the current situation. If he had checked he would have known that in the past most of the changes made had been suggested by the foreman. More important, the women in the department had always been consulted about the changes before they were put into effect. In some cases the ideas had come originally from a woman in the department. This should have been warning enough that changes introduced by an "outsider" without discussion with the employees were likely to cause trouble.

This discussion has taken us to the verge of enumerating some of the principles that might go into a handbook of the sort referred to. Recognizing the fact that we are perhaps not yet ready for such an undertaking, we can nevertheless take a step in that direction by analyzing briefly some of the human factors which tend to complicate the industrial engineer's job.

Non-Rational Behavior

1. Human behavior is often not rational.

This is a basic premise for anyone attempting to deal with the human factor. We still like to believe that human beings are essentially rational—that they think "logically" about most things. Unfortunately, this is simply not true. Our attitudes, beliefs and values—our biases and prejudices—affect much of our behavior. Anthropological and sociological research helped debunk the myth of rational man years ago when it discredited the concept of the "economic" man—the idea that a man always acted so as to further his economic interests. Yet we tend to ignore this fundamental in dealing with employees and unions, despite the evidence that employees frequently consider other things more important than money.

What precedes is not intended to leave the impression that behavior which appears irrational to one person may not be rational from another individual's point of view. This point involves an important source of conflict: differences in the assumptions made by different individuals. We shall return to this point shortly.

But much behavior is purely habitual and non-logical. A classic case was that of the middle aged man who nightly repeated a prayer which included a petition for the continued good health of relatives long dead. A more common exam-

ple is that of eating at a specified time, whether convenient or not.

The average person's objection to changing habits is often typically irrational behavior. Even proof that a change will benefit the individual or group concerned often does no good. Doing the same things the same way provides a sense of emotional security which most people are reluctant to give up. The rapid pace at which change is occurring in many areas of life tends to increase this reluctance to change work habits. The industrial engineer can therefore expect employees to be antagonistic and needs to find ways of overcoming resistance to changes he may recommend.

Neurotic behavior would fall into another category. Its importance should not be overlooked, however. If estimates based on World War II armed forces research are correct, a minimum of 50 percent of the adult population of the United States is neurotic. Many neuroses are not "visible," of course. But the related behavior may influence those who come in contact with the neurotic. The "driving" type of executive might be an example.

2. Ignorance tends to breed misunderstanding and antagonism.

Ignorance frequently produces not bliss, but headaches. This is especially true where the parties concerned have conflicting ideologies or belief systems. Mr. Robert Roulston pointed this out in his article on "Handling Grievances" in the November *Journal* when he confessed that as a union employee he ". . . didn't like [industrial engineers] because I didn't know what they were trying to do." He believed—probably typically—that industrial engineering benefited only the employer. The engineer who walks into such an atmosphere can expect trouble.

3. Beliefs and values determine what an individual "sees" in any situation.

This principle helps explain the cause of much conflict in industry. An employee's beliefs are based on his learning and experience. He ranks those beliefs (usually subconsciously) in terms of the value he has been taught to place upon them. The same is true of an executive or employer. Since the experiences of employer and employee tend to be quite different, they will bring different expectations and different values into most discussions. An individual will interpret what he sees and hears in terms of his experiences. If that experience is biased—and most of our experiences are—then his perceptions will be biased. The distortion is quite unintentional; there is nothing deliberate about it. But the effect is no less devastating. What one person sees as factual in a situation may differ radically from another person's perceptions of the same situation. In a very real sense, the "facts" are different for each.

4. Since the way in which any individual perceives a situation is "obviously true" to him, he will tend to attribute any differences of opinion concerning the "facts" to willful distortion on the part of the other person.

In this way the beliefs and attitudes a person brings into a situation are reinforced. When an employer hears a union representative present a version of "the facts" which does not agree with his own perceptions, his beliefs concerning the union representative's objectivity and purposes will be reinforced. Thus every encounter between persons whose perceptions differ tends to reinforce any biases which originally existed.

5. Ideological cleavage (the existence of different perceptions) will tend to make the communication of ideas difficult.

For this reason, as Peter Drucker and others have pointed out, company "propaganda" will tend to be a waste of money and effort. As long as employees remain convinced that their employer intends them no good, they will discount everything that comes from management. Similarly, company representatives will tend to discredit union proposals which may be made in good faith.

6. The status system of a factory exerts a profound influence on the behavior of employees.

"Status system" may be a bit of sociological jargon or an obscure empirical reality to the industrial engineer. But as a variable in the industrial situation it may prove a most realistic headache. A recommendation that an employee be transferred to a different machine or to another department may produce startling repercussions. Both jobs and departments are rated by employees. Where means of gaining status are relatively few these ratings may be jealously guarded. What appears to be an unobjectionable change or even a promotion to management may be considered an insult and a demotion by employees. Knowledge of this status system may therefore be extremely important to the "human engineer." Rate of pay obviously is an important factor. But transfer to a department or work group that has less prestige, to a location which is considered less desirable, or to a machine which requires less skill may more than offset wage increases. Here again the perceptions which the employee and the engineer bring to the job are important.

7. Motivation is produced primarily by "actional" rather than verbal communication.

This is a dressed-up version of the old adage "Actions speak louder than words." On-the-job behavior is more important to the worker than verbalizations. Executives who are sincere in expressing interest in employee needs and who spend large sums of money for recreational programs and other motivational devices often fail to recognize the counter-effect of existing policies and practices. Procedures or practices introduced by the industrial engineer in order to improve production may, in the worker's eyes, contradict avowed intentions of the company.

On the other hand, it will be unnecessary for management to spend money to "sell" employees on the company and to build loyalty if the actions of company representatives on the job tell the worker the "big boss" has an interest in him. An indirect approach in the form of actions will sell an employee long before verbal or written communications will. This does not mean that in situations where management's perspective is not known that no effort should be made to get it across to employees. In too many cases company aims and the beliefs and values of executives are virtually unknown to those at lower echelons. It does mean that such an effort is foredoomed to failure if actions fail to support it. Unfortunately, management personnel often think they know what their employees' needs and beliefs are when actually they do not.

8. The need to maintain one's self-esteem is important to morale and motivation; humans want to feel that they "count for something."

This has long been recognized in the rule "Praise in public, but criticize in private." But even this cardinal rule of human relations is often violated. Men who know better "chew" foremen in front of their men. Such an incident may be relatively minor to the boss, who may not even remember it; it will always be important to the worker.

Mass production has inevitably had a depressing effect on the worker's perception of his own worth and the contribution he can make to the overall productive effort. No one likes to feel that he is expendable. Whatever his job, an employee needs to feel that he is doing something important or worth while. Repeated manipulation of a man's job tends to have a depressing effect on morale and motivation.

9. Insecurity is "built in" the structure of an industrial organization.

Ignoring or discounting this idea is all too easy during a period when unions appear to have made members' jobs more secure than they have ever been before. The importance of job security cannot be denied. Emotional security on the job is often more important to the worker, however. The fact that his job and pay check are relatively secure may actually increase the importance of emotional security in the work situation. Not knowing whether he is performing well or when he may be "bawled out," not knowing what his supervisor thinks of him either as a worker or as a person may strongly affect an employee's performance and morale. Manipulation of his job and changes within the department can have a telling effect here, too. Where indoctrination has been weak and on-the-job training poor this will be especially true.

10. The frustrated worker will make mistakes and repeat errors until the

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Electronics—

A Useful Tool for Time Measurement Problems

By Alan J. Rowe

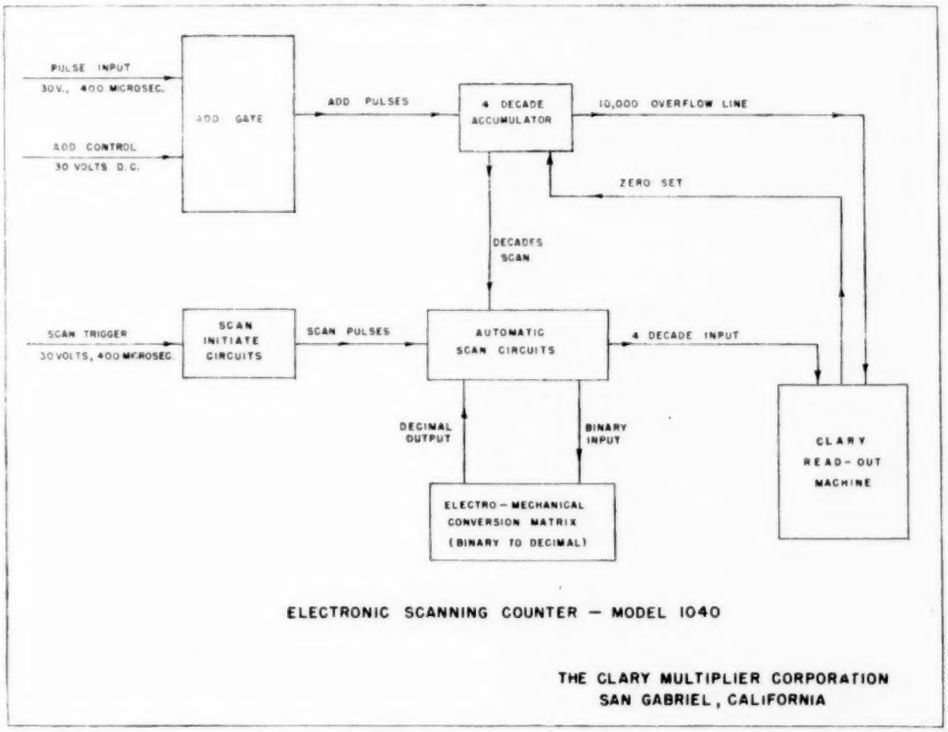
Assistant Professor of Industrial Engineering, University of Southern California

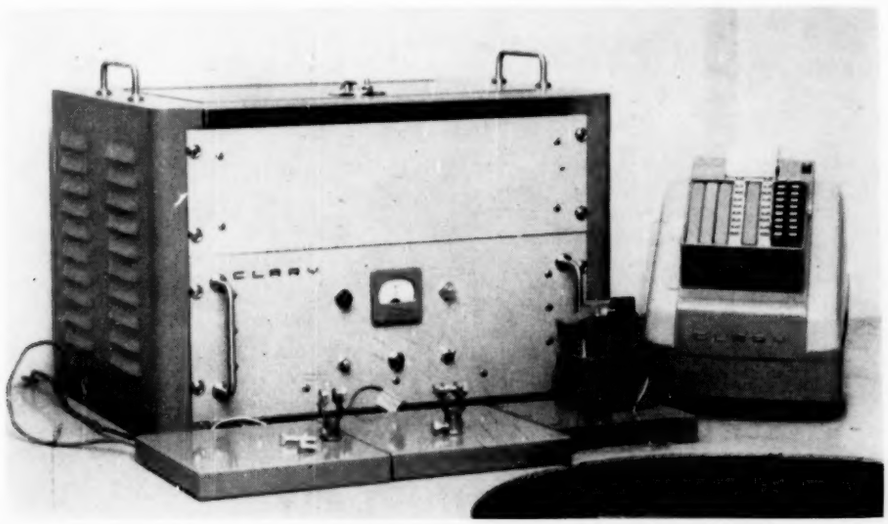
A need exists for an improved method of measurement of time in research problems and industrial applications where high accuracy is required. The stop watch has been most extensively used for the measurement of time, but its limitations are well known, and it is not suitable for accurate research work. The synchronous motor powered micro-motion and memo-motion cameras have the necessary accuracy but transcribing the data from the film to a usable form is tedious and time consuming. The marstochron and kymograph also have the requisite accuracy, but reducing the data is still a difficult problem. An automatic printing kymograph has the required accuracy and ease of data reduction, but it is not as flexible as an electronic timing device.

The electronic time measuring machine is a combination counting and printing unit. Its accuracy is obtained by use of a quartz crystal which controls the pulse input to an electronic decade counter. Time can be measured with this device to within one pulse per million, or an accuracy of one millionth of a second. The counter feeds the accumulated pulses into a read-out machine which prints the time as decimal seconds.

An experimental model of this equipment was built by the Clary Multiplier Corporation from standard electronic components. A simple task was employed to test the equipment at the Industrial Engineering Department of the University of Southern California. (Below is a photograph of the equipment while on exhibit at U.S.C.)

The task consisted of assembling two screws to a battery terminal connector. A fixture held the part as it was being assembled. A micro-switch was used to complete the electrical circuit needed to start and stop the counting. When a casting was placed on the fixture it tripped the micro-switch which in turn started the counting of pulses. As the connector casting was removed from the fixture, it opened the circuit which stopped the counting. Another casting was required to start the counting for the second cycle. While the second cycle was being counted, the elapsed time for the first cycle was being printed by the read-out machine.





This electronic time study machine is capable of measuring the time for each element of a cycle, as well as the total cycle time. This means a saving in the time required to extend the data to a usable form. In addition, the elements are added to give the total cycle time which is also a saving in time required to compute the data. The printer identifies each element of each cycle by printing an index number alongside the time value. Thus, any element can be singled out and identified so that reference can be made to abnormal values, fumbles, or other important information. Since the observer does not have to manually record the time, as in stop watch studies, he can devote his full attention to observing the workers methods as well as the rate of performance. This is an important aspect of any timing procedure. A special key is provided so that the performance rate can be coded adjacent to the element or cycle in which it occurred. It is thus possible to rate individual ele-

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Editorial Comments—

The Work Simplification Formula

By Robert N. Lehrer, Editor-in-Chief

Associate Professor of Industrial Engineering, Georgia Institute of Technology

Work Simplification is an important part of the "Scientific Management" movement that started more than fifty years ago with the works of Fredrick W. Taylor and the Gilbreths. It has long been used by the Industrial Engineer to increase the productivity of industrial facilities, and can be applied with equal effectiveness to improve any human work, from farming to surgery, from foundry to office. Work Simplification has not found wide acceptance in some areas of activity, even though the need is ever increasing, largely due to misunderstanding, and lack of an appreciation of the attributes of Work Simplification.

Rather than try to clear up misunderstanding by explaining what Work Simplification is not, let us examine the various things that lead to successful Work Simplification applications. In order to demonstrate the attributes of Work Simplification, we will use a formula. This will highlight the importance of each of the components, and serve as a graphic reminder that all of the elements are essential if success is to be had.

SWS = (PWS + tws)HF

WHERE;

SWS represents *successful work simplification*

PWS represents *philosophy and attitude of work simplification*

tws represents *knowledge of the techniques of work simplification*

HF represents *consideration of the human factor*

This formula, which is without mathematical equivalence, indicates the importance of the **HF** term. All terms in the formula are important, but, **CONSIDERATION OF THE HUMAN FACTOR** is by far the most important. Success with Work Simplification is impossible without adequate consideration of the Human Factor. Now—a more detailed examination of each of the terms.

SWS

Work Simplification is a systematic analysis of the factors that influence job performance, the application of principles of improvement, and the design of correct work procedures. Improvements result in the elimination of wasteful application of human effort and the maximum return for each unit of effort, money, or time expended.

Although definitions are formal, they do allow setting a proper frame of reference upon which to build the details of procedure. Work Simplification may be defined as a systematic analysis of all factors affecting work being done, or all factors that will affect work to be done, in order to save effort, time or money.

This definition may be expanded as follows:

Work simplification is:

1. The *analysis* of
   a. Product design
   b. Materials
   c. Sequence of events, procedure, or process
   d. Equipment
   e. Tools
   f. Workplace layout
   g. Hand and body motions
   h. Working environment
2. *Used or to be used* in the performance of work
3. In order to *save* effort, time or money by
   a. Elimination of unnecessary work
   b. Simplification of necessary work
   c. Making work as effective as possible
   d. Providing the best sequence for necessary work
   e. Standardizing product design, materials, sequence or process, equipment, tools, workplace layout, hand and body motions, and working conditions
   f. Installation of standard operating conditions
   g. Follow-up, evaluation, and corrective action (if and when needed)

This definition is presented in three parts to emphasize the importance of each. Work Simplification requires a thorough analysis of all factors that influence the effectiveness of human effort. It can be used as a corrective measure to eliminate poor work methods, or as a planning tool to prevent the establishment of ineffective work methods. The main objectives of Work Simplification are to make work easier, quicker, and cheaper.

The above definition could be restated in a simplified form. Work Simplification is the use of organized common sense to make work easier, cheaper, and quicker.

PWS

The Philosophy and Attitude of Work Simplification can be stated as follows:

1. There is always a better way to do a job.
2. The "One Best Way" is never achieved.
3. Work Simplification can be applied to most any work involving the expenditure of human effort if there is a desire to save time, effort, or money.
4. A systematic approach to better methods is superior to trial and error.

The Work Simplification attitude is a questioning attitude. Each unit of work is examined and questioned concerning its purpose and manner of execution. There is no place for "it can't be done" or "this is the way we always do it" attitudes. Our basic Work Simplification philosophy provides an excellent guide toward success, providing it is accompanied by:

1. An open mind (not an empty one) that is objective and interested in finding the necessary facts.
2. An inquisitive mind that continually questions and challenges, and
3. Imagination that will allow visualization of alternative work procedures and their effects.

HF

Work Simplification reduces the work content of work. In so doing, more work is accomplished by less effort in less time. This could mean that improved work methods would add up to less work for fewer workers in an individual organization, which might incite fear of losing jobs in the employee group. Workers must be assured that they will not lose their jobs as a result of Work Simplification before cooperation can be expected. Even with such assurance, most individuals will resist change unless the change has been suggested by them or *sold* to them. They must understand the whys of Work Simplification and the benefits they can expect to receive. Best results can be achieved when all employees understand Work Simplification to the extent that they actively participate in improving their own work.

Work Simplification helps employees and management achieve their common goal of stabilized plant operation for the mutual benefit of employees, management and owners, consumers and society. Work Simplification is a mechanism for increasing productivity. Increased productivity allows increased benefits for employees, owners, customers, and society.

tws

Work Simplification makes use of several analysis techniques. Basically they are simple and straightforward analytical procedures for gathering the facts of work performance. All of the techniques allow work to be classified as a series of small units of work. Work is not viewed as an overall job, but as a series of component steps possessing known characteristics. This sub-division of work allows treatment of the units of work according to principles of improvement. Various Work Simplification charts may be used to facilitate this analysis, but they are not difficult to use and are fairly easy to master.

All three factors leading to successful Work Simplification are important. HF (consideration of the Human Factor) is most important, tws (Techniques of Work Simplification) is the least important. Techniques are primarily a convenient and systematic way for gathering facts. PWS (Philosophy of Work Simplification) is very important from an inspirational standpoint. The relative importance of the three essential com-

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POINT TOWARD A GOAL

By Phil Carroll*

Professional Engineer

When I was trying to choose my future work, my Dad said "Son, I think Electrical Engineering is the coming field." Like too many men who look at job opportunity or big pay or nice work, I decided to be an Electrical Engineer. I pursued this course for 4½ years. After a tour of duty in the Signal Corps in World War I, I gravitated to Westinghouse in East Pittsburgh to start off.

All of us student engineers began work in the factory. For those who stayed on, there were two advanced courses open. One was in sales, the other in engineering. I did not know which course I wanted to take and so kept putting off the decision. One day the Chief of the Sales Training course sent for me. He asked if I had made up my mind to go into sales. When I said, "No," he asked me to make up my mind within the next two weeks. I replied, "No so and so is going to force me to decide in two weeks what I'm going to do the rest of my life." Naturally, I was out of the sales course.

During this starting period, as I went to and from my department, I passed certain of the engineering groups. In these offices, men wese sitting at desks pushing water-cooled slide rules. Most of them had Tau Beta Pi keys prominently displayed. This competition was too tough for me. Besides, I did not have any interest in working at a desk. These things decided me against "engineering."

HURRY TO CHANGE

Yet, like most youngsters, I was in a hurry to get some place. So nearly every night, I would talk over my indecision with my roommate. One evening he asked, "Why don't you try works management?" I didn't know what he meant. I had never heard of any such work. Just the same, I began looking around the next day. I learned that men preparing for that field were taking timestudies in the shop. Then and there, I knew what I wanted to do.

I found the man who arranged for transfers of those interested in timestudy work. I didn't leave him alone until I got a job—about two weeks later. Since then, I have been in a great many plants and in some disagreeable situations. I have had to study diligently to learn a field completely outside the one I "specialized in" at school. But nothing has caused me to change from that course I "pointed" over thirty years ago.

My first shift in type of work happened to turn out satisfactorily. It was so, more by good luck than good management. Not every man gets off to a satisfying start with only one shift. Many don't get started because they won't shift to some field other than the one they studied.

One Christmas, my nephew visited us while he was in school studying chemical engineering. He had selected that course because there was a big flurry in the field of plastics. He was told that there would be many openings for graduate engineers.

You may remember that during World War II, everybody was going to be an aeronautical engineer. I don't know what the current fad is.

IS EVERYBODY HAPPY?

Approaching your future work from the standpoint of job opportunities is a practical way. But is it the best way? Let me see if I can illustrate the point. Some years ago, a friend sent me a copy of his talk with a title something like "Communications in Industry." To this, he had attached a note asking what I thought. I read his paper and found a conclusion about like this: "If we had good communications in Industry, everyone would be happy." This bothered me. So I wrote him my reactions to what I think is one cause of "unhappiness" in industry. My reply was in the following vein. Youngsters stay in school only as long as they have to to escape the truant officer. Then they go out looking for a job that pays a lot of money. They already have a mortgage on a girl and an automobile. If they go down the east side of the street, they may become "butchers, bakers or candle-stick makers." If they go down the west side of the street, they may become carpenters, molders or timestudy men. From then on, they sell their experiences at the highest figure. And a great many stay on the wrong detour because of their seniority privileges. To this, I often add, "Maybe they should have been tuba players in the first place."

Myron H. Clark, past president of S. A.M., says, "It is estimated that less than 20 percent of the people who are in industry are in that kind of work for which they are best suited. This means that 80 percent go to their daily work wishing they were in a different vocation." [1]

If his figures are anywhere near right, no wonder we have such lack of interest, discontent, and turnover. No wonder we see so many references to "job dissatisfaction." But that is trying to solve the problem by trial and error. Too many of us work on remedies. I call it putting a patch on a patch. We spend too much of our time on detours. We may never get on the right road by that approach.

THREE KINDS OF IGNORANCE

In blunt words, our decisions as to what kind of work we should do are based on ignorance. We decide on the basis of what we know or what is told us by our parents or relatives or friends. Some of their advice is based on "job opportunity," "the chances are better." Some emphasize their advice with the dollar sign, "There is big money in that work." Other people may ask about interest, "What would you like to do?" Here we come to one form of ignorance. How could you like or dislike a kind of work that you have never experienced?

As Andrew Salter puts it, "No one does what he should, he only does what he can, because that is what he is conditioned to do." [2]

In about the same words, Rudolph Flesch says, "Don't forget that everybody, including yourself, has only his own experience to think with." [3]

Along with this goes a second form of ignorance. What are your aptitudes? What are your potential abilities? What kind of work can make the maximum use of the abilities you have?

To these two, I would like to add a third form of ignorance. It relates to the degree of application of one's aptitudes. Because most of us have several aptitudes, we can utilize them in different degrees as we progress up the ladder. If this is true, then I suggest that there is only one job that can be made to fit you as an individual. That is the one where you can cut the cloth to fit. I illustrate by saying, "This vice president signs all his checks because he has a certain amount of clerical aptitude. The other vice president refuses to take care of any clerical details because he has no clerical aptitude." Both are changing their jobs to suit their aptitudes.

YOU MUST CHANGE HORSES

In this respect, the Industrial Engineer is even more confused. He studies in college to be an expert in a specialty. Before he can get any place in industry, he must do a great deal more studying. He works diligently at what I call "shrinking the knothole." He strives to become more and more expert in a smaller and narrowed specialty. Besides, nearly all "Industrial Engineers" work as staff men.

Sooner or later, to get ahead, they must shift from technical specialists to

*Author of Timestudy For Cost Control
Timestudy Fundamentals For Foremen
How To Chart Timestudy Data
How To Control Production Costs

[1] Clark, Myron H., *Training Engineers to Handle Men*, S. P. E. E., Pennsylvania State College, 1939

[2] Salter, Andrew, *Conditioned Reflex Therapy*, p. 35, Creative Age Press, New York, 1949.

[3] Flesch, Rudolph, *Art of Clear Thinking*, p. 52, Harper & Bros., New York, 1951.

managers. In their upward progress, there are three paths open to them, as I analyze the change. One is to move upward in the staff side of the enterprise. The top job in this path is Controller. Many shift over onto the other main highway and head for the Presidency. A third route some follow is to go into the consulting field. Obviously, some may shift from any of these main highways to any other as they move upward in the field.

Which way should you point? How will you know whether you are on a main route or a detour? Are you pedaling along too rapidly toward the southwest when you should be pointed northeast? If you don't know where you're going, how will you know when you get there?

INDECISION SLOWS YOUR SPEED

Now we come to another phase of this question of "What job?" If you are like I am, you poke along on a highway that you are not sure of. You take it easy until you get your bearings. You lose a lot of time like I did a couple of weeks ago. I wanted to go to Willimantic, Connecticut. I was told to take Route 6A. To start off with, my advisor said that I would turn off the Wilbur Cross Parkway in six miles. I lost time because the junction did not show up until I had gone nine miles. Then I had to feel my way for nearly forty miles because the road was not well marked. But that was not my chief difficulty. The town I was headed for did not show up on any road signs until I got within about five miles of Willimantic—my destination.

Because we don't know where we are going, we may drift. We may sit around just waiting for dead men's shoes. We keep our noses clean and wait for promotions. Many lack the courage to make a change even if they have found out that they are in the wrong place. They think twice about making a move because of "the wife and children at home." Maybe they owe everybody and his brother for their new houses, new automobiles, new refrigerators, new washing machines, and new TV sets.

THE GREENER PASTURE

Under the pressure for more money, some fellows look over the fence to a greener pasture. A young man I helped to train saw such a greener grass some years ago. He came to ask my advice about taking a job in another plant that paid five dollars more per week. Five dollars a week was a lot of money around 1938.

Bill was a skilled timestudy man. He had been with his present employer for seven years. He worked for a client company. Strangely enough, the new job he was looking at was with another client company. That put me in the middle.

We spent about three hours trying to solve his problem. I started off by asking, "Where do you want to be five years from now?" He didn't know. Yet he had a good reputation in his company of seven years standing that he was willing to sacrifice for five bucks a week. Trying to make him take stock of his present situation, I asked, "Who is the best man in your plant? What are his qualifications?" He named the Works Manager and we talked a great deal about his abilities. Then I asked, "What has he got that you lack?" We talked about Bill's shortcomings for awhile and then I wanted to know who was the next man in line. Bill named him and we went over his qualifications as compared with Bill's. Then we moved on to the next man in line and went through the same analysis.

When we came to the fourth man in progression, there was some question. Bill indicated that maybe he was in that position. Then I said, "You would give up the fourth place in line for five dollars a week." At this point, he wasn't so sure.

PICK A GOAL

Then I asked him what he was doing to prepare himself to move ahead. He said that he read the newspapers and listened to the radio. But he did not do any studying. He attended very few meetings of the engineering societies. He held no offices and did no work on committees. He spent no time at all rolling stones out of his path of progress but worried about why he didn't make more money.

He had to decide whether to stay or to move. I couldn't help him very much. However, I did suggest that whether he took the new position or stayed in his old plant, he had to "point toward a goal." He had to pick out a job ahead of him and make every move count to insure that he got it. I emphasized in words of one syllable that when he got that job, he might not want it as badly as he thought. Undoubtedly, in the meantime, he would have moved his goal further ahead.

A few months after our talk, his boss told me, on the side, that Bill was making great progress. About a year later, Bill came to me at one of the chapter meetings, stuck out his hand and said he was to be congratulated. "Remember our talk?" he asked. "Well, I got a promotion *and a raise*." Bill had not done anything that he could not have done before. He had moved ahead because he pointed his course toward a definite goal.

POINT YOUR SKYROCKET

That reminds me of my old friend, Herbie. When I first went to Wilkinsburg, Herbie had an old flivver that we used to run around in. That old Ford never failed to take us where we wanted to go. Herbie always knew the way and pointed his course to take us there and back with the minimum of detours.

Some years later, I saw him sitting behind the wheel of a shiny modern automobile." My first question was, "How do you like it?" He said, "Fine. But there's one thing you have to look out for with these new automobiles. It took me quite awhile to get used to this one. I have to *point* it before I step on the starter because it takes off like a sky rocket."

Many young graduates take off like sky-rockets. They plan to be vice president in the third or fourth week, at the latest. Many refuse to go to work in the plant. They want to be in the office where they are closer to the vice presidency. They *are closer* in feet. They are miles away in experience.

YOU CAN GO PLACES

Nearly any Industrial Engineer who wants to get some place can do so if he is willing to work and study. Many timestudy men I have had a part in training have made unusual progress. Perhaps that is because I have always carried a generous supply of "turpentine" with me. I do believe, however, that timestudy men, as a group, have more chances for getting ahead than most other members of an organization.

Timestudy men know more about the details of manufacturing than any other folks in the plant. This assumes, of course, that they use their powers of observation. More than that, they have to learn to get along with people in order to produce results. They have to learn the functions of practically every department in order to attain the objectives they are trying to reach. These opportunities to learn and assemble facts place the timestudy man in an enviable position to make progress.

Then too, timestudy men have more than average opportunities to display their capabilities. Often, they are sent for by executives up the line who have questions to be answered. Good timestudy men are frequently called upon to carry out special assignments. They may be asked to make studies and present their conclusions. What better opportunities could one ask for to register his personality and his capability?

The man who has laid his foundation well and can conduct himself properly in the presence of top management has more than ample opportunity to "get ahead."

MAKE YOUR OPPORTUNITIES

But you have to be ready. To explain this, first let me give you an idea I think is correct. I say, "The company can pay more without raising costs only for more output or higher skill." The Industrial Engineer has elected to make his money with his mind. That means he must build up higher skill to get each successive promotion. How many do so beforehand to insure progress? Not many. Usually, the company loses money for months or years because the man starts to learn more only after he is promoted. Many times, younger men have said to me, "I think I'll take some courses"—after they were catapulted into bigger jobs. I ask you, "Is that good planning? Is that the way to prepare for your future?" I think I know the answer. I feel certain that "it's waiting" for opportunity. Just

(Continued on page 15)

Mathematical Methods in Management Programming

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The production control function too often is not recognized as being one of the most important functions of industrial management. Often the industrial engineer, as "management's" engineer, is assigned to many limited-scope problems, such as developing a "one best method" of assembling a product, developing wage incentives, or other. These are important, it is true, but they are far less important than the "profit governing decisions" made through production control. Even F. W. Taylor recognized early in his career that good work methods, for example, are neither necessary nor sufficient to assure good profits. Profits depend heavily on other factors, primarily top management actions and decisions, and these depend heavily on the planning and control function in production.

Alford in his "laws of management" came close to a correct statement of the objective of production in his law "The Highest Efficiency in Production is Obtained by Manufacturing the Right Quantity of Product, of the Required Quality, at the Right Time, by the Cheapest and Best Method." ("Method" is only one of the five determinants of Alford's "efficiency.") However, this law is only at best a tautological "common sense" statement. If we inspect it closely we see that "highest efficiency" is in fact defined by the conditions which determine it, and vice versa. He gives no systematic and objective criteria for measuring "efficiency" or for determining the independent conditions. The law even becomes wrong under one possible interpretation, i.e., we cannot minimize or maximize five variables simultaneously which we cannot assume are independent, and necessarily obtain a maximum in the dependent variable. In other words, there is an interdependency between "required quantity, required quality, required time, cheapest and best method. They must be solved simultaneously if we are to maximize some dependent criterion function, such as profit. Indeed, this is the essence of the method we are to present here.

Production control is concerned with the basic decisions: "what to produce, how many to produce, how to produce, and when to produce." The first three of these are concerned with "planning" while the latter with "scheduling" (although as we shall see, there even is an interdependence between planning and scheduling). Scheduling usually refers particularly to the selection of time or "when" of production, largely with the assumption that the other factors are held constant. It is an important function: it often is expensive and always necessary. Its cost is not only the salaries of schedulers and their usual Gantt Chart or similar paraphernalia, but also the salaries of expeditors, material chasers, dispatchers, production clerks, and in part the foreman. It indirectly shows up in the cost of production by idle time, interferences and delays, shortages, etc.

Bethel has defined scheduling to be "fitting operations into a logical timetable." This is again good common sense; but it is of little or no use when it comes to actually scheduling.

We now will consider a few methods which can be used in production control and in which are incorporated quantitative criteria for measuring "logical," "efficiency," etc. They include systematic techniques for computing for the most logical or efficient program. We will speak here of an "objective function." This is another way of describing the purpose or objective of a firm. That is, the objective of the firm is to maximize profits; we express this objective in a mathematical function. We take the fundamental position that the firm wishes to maximize its objective function, i.e., maximize its profits. We assume, therefore, that it carries out its production control and scheduling activities in such manner as to maximize its objective function. By our definitions, that production program and schedule which maximizes profits is the one with the "required quantity, right time, required quality, best method, and cheapest method." but, the profit in management is the dependent variable—it is determined by the decisions and actions which we take in regard to the quantity, quality, timeliness, and method. Hence, we will consider these to be the independent variables, and will examine how we can select their value consistently to maximize the function (or profit).

The Objective Function

Let us assume that total profit is denoted by $f(x)$. Let us assume that the amount of a commodity we make is denoted by "x." Let us also identify each commodity by attaching an identifying subscript, say, i. Finally, let us denote the time at which any commodity is produced by a superscript "t," indicating, say, the day, month, or other in which it is produced and sold. For the moment, let us assume we have a reliable measure of the profit on each commodity we are to make during each time period. Let us denote this by a^t_i. Then, the total profit is equal simply to the sum of the products of the amount made of each commodity during each time period by its profit during that period. That is;

$$f(x) = {}_i\Sigma_t \; x^t_i \; a^t_i$$

Restrictions on Profit Functions

No practicing manager or engineer needs to be told that he has many limitations on his plant's capacity to maximize profits. There are limitations on the supply of capital, manpower, machine tool time, material, power, tooling, etc. At any time, any one or more of these may limit the maximum profit. Hence, in the words of the economist, we wish to "allocate" the use of his capacity of those factors which are his "bottlenecks" in such manner as to obtain the production program with the maximum profit.

Every production manager knows, of course, that time, money, and material are universal requirements. Most shops, indeed, have "standards" for the amount of each of these which is required for any commodity. These may be called by such familiar names as "time standards," "standard costs," or "bills of materials." We assume (for mathematical reasons) linear relations in these requirements, i.e., for example that it takes ten times as much material to make ten units as it does to make one; ten times as long to make ten units as it does to make one, etc. This is a familiar concept, that the total requirement of any factor for making any one item is equal to the product of the unit requirements by the number to be made. In expressing this, let us use notation as before, but add a second subscript to denote which factor of production, (money, machine, tool, labor, or other) we may be considering and let that be the symbol "k." Let us also use the notation "b" to indicate unit requirements. Thus, x^t_{ik} would denote the amount of the *ith* item produced during time period t using the *kth* factor of production. b_{ik} would indicate the unit requirement of the *kth* factor for producing the *ith* item. Thus, the total requirement on any one factor k in any program would be:

$${}_i\Sigma_t \; x^t_{ik} \; b_{ik}.$$

If all factors of production were not available in limited supply, we should not be here today to worry about the problems of production control. But, since they are, we must reckon with this fact; it is the source of ever present bottlenecks. Let us assume that we have only an amount c^t_k of any factor k during any time period t. It is common knowledge that the amount of any factor which is planned to be used must be equal to or less than the amount that is available.

This relationship we can state as follows:

$$\Sigma_i \; x^t_{ik} \; b_{ik} \leq c^t_k$$

Empirically, it is obvious that we cannot have negative production, so we add the obvious restriction that:

$$x^t_{ik} \geqq 0$$

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We define,

$$x'_i = \Sigma_k \; x'_{ik}$$

Thus, we have our beginning mathematical problem. Maximize:

$$f(x) = \Sigma_{ik} \; x'_i a'_i$$

subject to satisfying the requirements that:

1. $\Sigma_i \; x'_{ik} \; b_{ik} \leq c'_k$
2. $x'_{ik} \geq 0.$

We can use this formulation for such problems as:

1. to determine the optimum shop load during any one time period or over several time periods.
2. to determine the optimum amount of overtime to use on any item or machine tool.
3. to determine the optimum mix of commodities to make in the shop or factory.
4. to determine the amount of rerouting of work in the shop.
5. to determine the optimum level of inventory (raw, in-process, and finished.)
6. to determine the optimum distribution of production of commodities between time periods.

However, it is important to point out what this formulation will not do and what its inherent limitations are. It is not able:

1. to determine a schedule for a shop.
2. to select the best sequence of production in order to minimize, say, set up time.
3. to eliminate need for expediters.
4. to avoid all conflicts in production, such as temporary bottlenecks and hence, its program is not necessarily always achievable (unless it is constructed with overly liberal delay allowances.)
5. to give delivery dates more precisely than the length of its time periods.

It does not consider several important aspects of production, although they often may be "gotten around" by various tricks. For example,

1. It assumes certainty, i.e., it does not predict rejects, worker absence, market fluctuations, or other. These are assumed to be known on some average basis and that average is usually used in the computations. It does not provide a means, for investigating the effect of perturbations.
2. It assumes linearity throughout. That is, it neglects the non-linearities of "learning" by the operator, of set up time, of increasing returns to scale in production and decreasing sales price on increasing sales volumes.
3. It assumes continuity. It neglects "lumpiness", or the fact that machine tools come in discrete units; it effectively assumes that production of all items to be produced is simultaneous and continuous during the period and that production is not complete on any item until the end of the period. (Which is why it will not select exact time or time schedules.)

It is seen, therefore, why this is termed only a beginning formulation of the problem. Nonetheless, it is highly useful. It permits better answers than are attainable by present methods for the problems to which it is applicable. But it is not the "ultimate" solution to shop problems.

Illustrative Example

Let us now consider a small scale example of making a decision on a production program and see how the method of representation and computation may be used. We will carry it through in some detail. Thereafter, we will show only how other types of problems may be placed in the necessary computational form, leaving to the reader the task of using the same computational algorithm to obtain a solution for them. The first example is deciding on the optimum mix of commodities to produce during one time period when there is an unlimited supply of all factors of production available, except machine capacity.

We assume only the following in this problem. The enterprise has two commodities which it can make, say machine screws of types 1 and 2. It can sell as many as it makes at a constant price and the material which it buys for these screws is available in unlimited supply at a constant price. Also, labor is available in unlimited supply at a constant wage. We can say, therefore, that unit profit is constant and we take here to be the difference between variable costs (labor and material) and sales price. (We omit an interesting economic and accounting problem at this time on the correct method of handling overhead costs.) The enterprise also has an adequate supply of labor available which can operate any of its productive equipment at the same wage scale. Also, we assume that any operatives not required will find employment elsewhere. The firm has two machine tools used for making the screws. Each tool has a specified number of productive hours available during the period for which we wish to establish a program. We assume that the manager of the enterprise wishes to select the kind and number of screws to make which will give his company the maximum profit.

We now can begin to state this problem mathematically. Let us use the variable x_1 to indicate the number of screws of type 1 which we wish to produce in the optimum program, but which is as yet undetermined. Let x_2 be the same for screws of type 2. If, then, the unit profit of type 1 screws is 3 cents and the unit profit on type 2 screws is 4 cents, we will maximize profit $f(x)$ if we select x_1 and x_2 so as to maximize the sum:

1. $f(x) = 3x_1 + 4x_2$

Now, suppose, also, that each screw must be processed on each of the machine tools; machine 1 slots the heads, and machine 2 turns the threads. The amount of time in minutes required of each machine tool for processing one unit of each type of screw is:

	Machine Tool	
	Machine 1	Machine 2
Screw 1	2 Min.	5 Min.
Screw 2	3 Min.	2 Min.

These numbers are those typically determined by the time study department of a factory or office (they may be estimates, time studies, synthetic data, or other). For the period during which we are to develop the production program, assume that there are 3600 minutes of productive time available on each of the machine tools.

Now, we introduce the capacity restriction in the problem to assure that no machine is overloaded. Hence, we can state that the sum of the times required for processing selected amounts of both screws on machine 1 must be equal to or less than the amount of time available on machine 1. We can say the same for machine 2. These requirements can be stated mathematically as follows:

2. Machine 1: $2x_1 + 3x_2 \leq 3600$
   Machine 2: $5x_1 + 2x_2 \leq 3600.$

Inasmuch as we are concerned in the real world only with "irreversible" processes, we cannot put in finished screws, run the machines in reverse, and obtain the same amount of bar stock, electrical power, unused tools, etc., as those with which we began any process. Hence, we must add the further restriction that:

3. $x_1 \geq 0,$
   $x_2 \geq 0.$

Now we may summarize the problem in mathematical form as follows:

2.1 Maximize;
$3x_1 + 4x_2$

subject to satisfying limitations on machine time capacity:

2.2 $2x_1 + 3x_2 \leq 3600$
2.3 $5x_1 + 2x_2 \leq 3600$

subject to not having any processes operating in reverse:

2.4 $x_1 \geq 0,\ x_2 \geq 0.$

A geometrical interpretation of the mathematics might be helpful in visualizing the problem. Let us construct a graph with two axes. Axis 1 represents the amount of screw 1 which is produced and axis 2 the amount of 2. Inasmuch as x_1 and x_2 are constrained to being equal to or greater than zero, we need only consider the positive orthant of this two dimensional graph. On this graph, let us plot the amount of both screw types which can be processed on each machine without exceeding the capacity of that machine. This will mean two "lines of capacity"; one for each machine tool. On the graph which follows, line 1 refers to the upper limit of capacity of machine 1 and line 2 to machine 2. Line 1 is plotted, for example, by letting first x_1 be assumed equal to zero and then computing from 2.2 ($2x_1 + 3x_2 = 3600$) the largest value of x_2 which satisfies that inequality. In this case, the values are ($x_1 = 0$, $x_2 = 1800$).

Indeed any other point on this line is represented by the intersection of the two lines representing its values in each of the two coordinates or axes. These other points may be determined for example by the table below wherein we chose first x_1 and then compute x_2. The result of plotting all possible points would be line 1. Because this is a "linear" inequality, we could have determined the line by any two points.

x_1	x_2
0	1200
1800	0
150	1100
300	1000
450	900
Etc.	Etc.

Technically, if we consider only integral numbers of screws we would have a series of points rather than a continuous line.

Line 2 representing upper limit for capacity of: $5x_1 + 2x_2 = 3600$

x_1	x_2
0	1800
720	0
20	1750
40	1700
60	1650
80	1600
100	1500
Etc.	Etc.

With these tables and the method of plotting, we now can illustrate geometrically the meaning of the two machine capacity limitations and the non-negativity restrictions. The graph in this problem is shown in Figure 1.

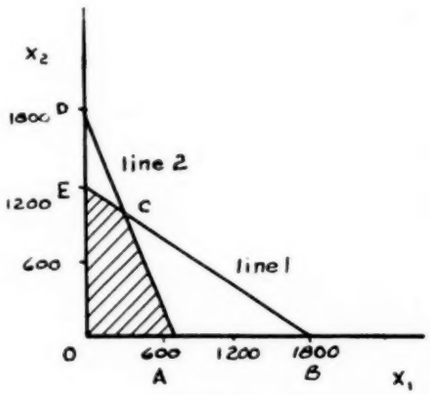

Figure 1

With this graphic portrayal, we see that we cannot process on machine tool 1 any combination of quantities of screws 1 and 2 which when plotted in the indicated manner falls above the line 1. We can produce less than the amount indicated by the line of capacity, however, by letting the machine stand idle some of the time. Hence, the "feasible" programs insofar as machine 1 is concerned would be all of those points (x_1, x_2) inside (nearer to the origin) and along the lines defining the triangle OBE. By similar reasoning, the feasible programs for machine 2 would be those points inside and along the lines of triangle OAD. But, since we can make finished screws only by using both machine tools and carrying out both operations, we must satisfy *both* machine tool capacity limitations. Hence, we are limited to programs which are feasible on both machine tools. The jointly feasible programs are those defined by the points inside the area common to both capacity limits, namely to the shaded polygon OACE.

Thus far, we have described only what programs the enterprise *can* carry out considering the limitations on productive capacity. Our next task is to determine, under the given conditions, what program it *should* carry out in order to achieve its objective, i.e., maximize profit. To do this, we must introduce the profit maximizing form, 2.1. Through this form we know that for any given combination of quantities to produce, we can uniquely determine the profit which will be earned. For example, if a program specifies $x_1 = 150$ and $x_2 = 1100$ (taken from line 1 because it is the capacity restriction in this region), the profit is:

$$3 \times 150 + 4 \times 1100 = 4850.$$

Hence, by the same method as before, we can plot as the third dimension on the graph in Figure 1, the profit from any productive program. The graph of the profit considering the restriction imposed by machine 1 would be as shown in Figure 2.

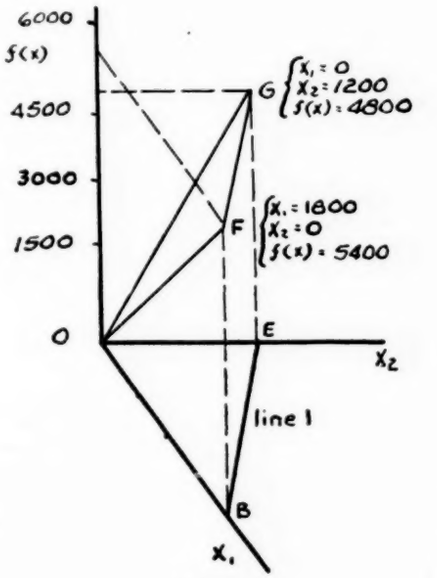

Figure 2

In Figure 2, the profit for any program as given by a point in the triangle, OBE, there is a corresponding profit given in the triangle OFG, and the height of this point is the profit.

The graph of the profit considering the restrictions imposed only by machine 2 would be as shown in Figure 3.

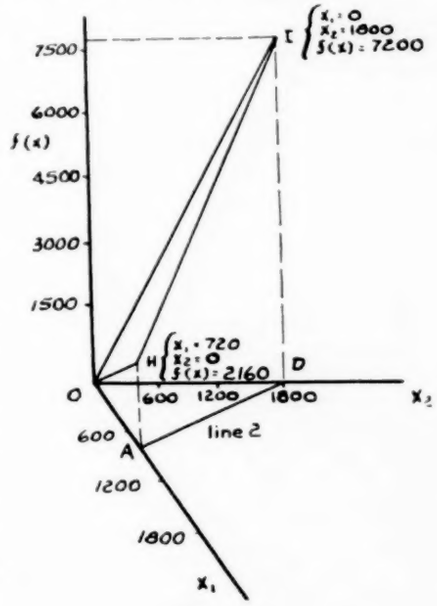

Figure 3

It is recalled, however that we are limited to a program which is feasible under both machine tools' capacity restrictions. The graph of the profit under both these restrictions would appear as in Figure 4.

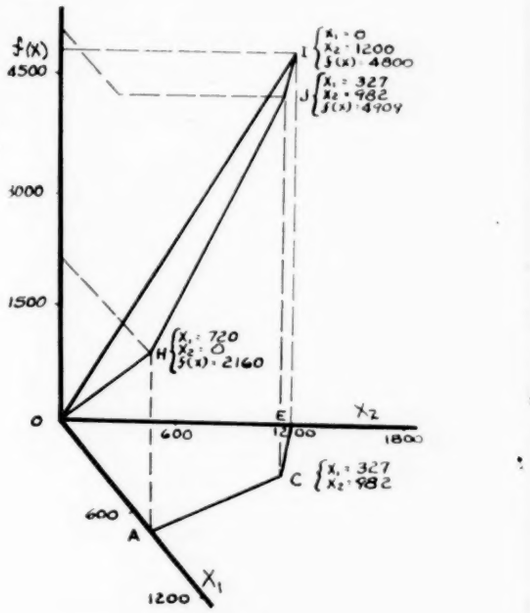

Figure 4

Now by inspection of these graphs we can see several interesting properties. For example, in Figure 2, we see that the "optimal" (most profitable) solution or program with respect to machine 1 is that which produces all possible of screw 1, whereas in Figure 3, we see that the most profitable from the point of view of machine 2 is production of all of screw 2. However, we can see also, the obvious property that is profitable (under the assumptions of this problem) to produce all that is technologically feasible, whether that be screw 1 or screw 2. As we shall prove later on, but use heuristically now, this means that the optimal program will always be at some corner, such as point, A, C, or E in Figure 1 (or at 0 in case it is not profitable to produce at all). Hence, in this case, we need compare the profitability of only these three points as follows:

Point	x_1	x_2	P
A	720	0	2160
C	327	982	4909
E	0	1200	4800

In this particular problem, the most profitable program is Point C in Figure 1 or Point J in Figure 4.

COMPUTATIONAL METHOD

One very important aspect of "model building" for managerial problems is that of computation. In the illustrative problem in the preceding section, the number of solutions which could have been optimum was so small that it was possible to enumerate them and choose from among them that one which is best. In the more general case, it is necessary to use other and more powerful methods of finding the optimum.

We can readily see in the illustrative problem that it would have been possible to use the theorem that as much as pos-

sible will be made, whatever that combination of screw 1 and screw 2 may be. In this case, it would have seemed possible to simply set up the two inequalities 2.2 and 2.3 as equations and solve for their intersection since in this problem that is where we found the optimum to be. However, in the general case this method will not necessarily give optimal solutions because:

1. There may be more unknowns that equations, and hence, no unique solution would be forced by this method.
2. The intersection of the lines of capacity would not necessarily be at one point. Further, by a simple change in profits between screw 1 and screw 2, it would have been possible to have the optimum solution or program lie at point E or A of Figure 1.

The following computational technique, called the simplex method for programming is largely due to the work of Dantzig. There are other methods, but for pedagogical reasons, we will not explore them all at this time. In any case, an adequate understanding of this method will be helpful in understanding other methods. Research is continuing, and improvements may be expected.

In order to explain the simplex method, refer to figure 4. It operates on a straightforward principle as follows: We begin at any point, such as O, A, B, or C, usually, however, at O because that is usually the only point we know reliably both where we are and that the program is technically feasible. At that point, we compute whether or not there is one or more other points that are both more profitable and technically feasible. We then proceed to that next point toward which there is the greatest unit rate of profit. We compute what that point is, and then repeat the cycle until we find that there are no other points which are better. This point will be at least as good or better than any other.

In order to illustrate this method, we now proceed with a step by step illustration of the computational method. The first step will be to find the point O. The second step will be to find point I. The third step will be to find point J. The final step will be to prove that no other point is better than J. These steps are as follows:

Step I: First, let us introduce the concept of "dummy" or fictitious screw types which we may think of as being produced, but which, in reality, represent "idle machine time." Screw type 3 then is the idle time on machine 1, and screw type 4 is idle time on machine 2. Hence, any time not devoted to "real" production is conceived of as devoted to production of these dummy screws. The profit on the dummy screws is, of course, zero; and their unit rate of production is 1.

The mathematical problem becomes, then:

$$\begin{aligned} \text{Maximize: } & 3x_1 + 4x_2 + 0x_3 + 0x_4 \\ \text{Subject to: } & 2x_1 + 3x_2 + x_3 = 3600 \\ & 5x_1 + 2x_2 + x_4 = 3600 \\ & x_1,\ x_2,\ x_3,\ x_4 \geq 0 \end{aligned}$$

As an aid to computation, we can express the problem in a slightly different format by using a table such as Table I below. This table should be read as interpreting "+" signs between the numbers in any row where separated by a single vertical line and an "=" sign where separated by a double vertical line. Also, the variable x_i (i = 1, 2, 3, 4) at the top of any column should be interpreted as multiplying each of the numbers in the column below it. The numbers in the column headed "C" are the productive capacity in minutes for the machine tool which is represented by the row in which the numbers appear.

TABLE I

	x_1	x_2	x_3	x_4	C
Machine tool 1:	2	3	1	0	3600
Machine tool 2:	5	2	0	1	3600

The first step in this method is to select an assuredly feasible solution. This would be that solution for which $x_3 = 3600$ and $x_4 = 3600$, $x_1 = 0$, $x_2 = 0$. It would represent producing nothing and making no profit.

By a simple change in Table I we could denote this as the initial solution. We write it as:

TABLE II:

S		x_1	x_2	x_3	x_4	C
↓	↓					
	x_3	2	3	1	0	3600
	x_4	5	2	0	1	3600

and think of the *solution of the problem at this step* as involving x_3 and x_4 as indicated under the column headed "S," and with values equal to the numbers in the column headed "C." We would have then the initial solution $x_3 = 3600$ and $x_4 = 3600$. This indeed would satisfy the "capacity" limitations; it would specify a program with 3600 minutes of idle time on machine 1 and 3600 minutes of idle time on machine 2.

This program is, of course, "feasible," but may not be "optimal." Hence, now we wish to take another step and get a "better" solution if such exists. We wish, also, to obtain such intermediate solutions as will take us via the shortest or most economical route to the optimal program. (Usually the method here will be the most economic.) To do this, let us rewrite Table II as follows:

TABLE III:

P ⟶		3	4	0	0	C	T
	S	x_1	x_2	x_3	x_4		
↓	↓						
0	x_3	2	3	1	0	3600 = 0	
0	x_4	5	2	0	1	3600 = 0	
							0

Table III is the same as II, except that a row and column marked "P" have been added at the top and the extreme left. Each number in that row or column is the unit profit of the screw which is indicated by the subscript of the x which is immediately below or to the right of it. The total profit from any intermediate or final solution is indicated under the column headed by "T" is the sum of the entries in that column. These entries are obtained by multiplying corresponding entries under column P and column C. With the preceding, we have completed Step I and are ready to begin Step II.

Step II: In order to determine which screw will be most profitable to bring into the solution, do the following. Take the unit profit of each screw type not in the solution, x_1 and x_2, and subtract from it the profit on screws already in the solution which would be lost if one unit of that screw were brought into the solution. For example (1) take the unit profit on screw 1(=3), (2) compute the sum of unit profits which would be lost: if one unit of screw 1 were produced, and (3) subtract the number determined in (2) from the number determined in (1).

Unit profit gained on screw 1 . . . 3
Profit lost on screw 3,
unit 1 . . . . . 2 x 0 = 0
Profit lost on screw 4,
unit 1 . . . . . 5 x 0 = 0
0 0

Unit profit weight of screw 1: $w_1 = 3$

Repeat the computation for the remaining screws not in the solution at this step.

The significance of these operations is as follows. If one unit of screw 1 is brought into the solution it will contribute its unit profit. But, simultaneously it will take productive capacity away from the screws that are already in the current solution. Since producing one unit of screw 1 will take 2 minutes of time on machine 1, it will take away capacity for 2 units of screw 3; similarly, it will take away capacity for 5 units of screw 4. Hence, in order to determine whether or not it is profitable to bring any one screw into the solution, we must take its unit profit and subtract from that the total profit which would be lost on the other screws which its production would preclude.

This operation thus computes the *net unit profit* which would be obtained by bringing into the current solution one unit of each of the screws not already in the solution. The screw with the largest profit weight w, is the one which should be brought next into the solution. The profit weighting function for each screw as computed by this method is written under its corresponding column as in Table IV.

TABLE IV

P ⟶		3	4	0	0	C	T
	S	x_1	x_2	x_3	x_4		
↓							
0	x_3	2	3	1	0	3600 = 0	
0	x_1	5	2	0	1	3600 = 0	
							0
w ⟶		3	4				

In this case, the screw with the larger net unit profit is screw 2, with a value of 4. This tells us, therefore, that we want to go along the x_2 axis in the graph in Figure 4, from point 0 to point I.

In the computational method here, we find this point as follows: Compute the amount of screw 2 that we can bring into the solution by dividing each entry in the column under x_2 into the capacity of the machine tool corresponding to the row in which the entry is located. Spe-

cifically, in the row opposite x_3 we divide

$$3600/3 = 1200$$

and in the row opposite x_4 we divide

$$3600/2 = 1800.$$

This computes the number of units of screw 2 respectively if machine 1 and machine 2 were devoted full time to producing screw 2. It is simply dividing the productive hours available on each machine by the production standard for one unit of screw 2 on that machine.

It is recalled from the graph in Figure 1 that we are limited to solutions within the shaded area. This area delimits by the combined capacity for both machines. Obviously, therefore, we must choose an *amount* of screw 2 to produce which does not exceed that capacity. Hence, in order that we may include an amount of screw 2 in the solution which is up to, but does not exceed, the lower of the two capacities, we must take the lesser of the numbers so determined, i.e., 1200. The results of this computation are summarized in Table V.

TABLE V

P→		3	4	0	0		C	A (amount)
	S	x_1	x_2	x_3	x_4			
0	x_3	3	3	1	0	‖	3600	3600/3 = *1200*
0	x_4	5	2	0	1	‖	3600	3600/2 = 1800
w⟶		3	4					

We must now account for the changes which this has made in the shop load. This we do as follows in Table VI with a tabulation of the values at the beginning of this step, the changes, and the values of the end of the step.

TABLE VI	x_1	x_2	x_3	x_4
Solution of the initial step	0	0	3600	3600
The changes to be made in the initial solution	0	+1200	−(1200 x3) =−3600	−(1200 x2) =−2400
New, or current step's solution	0	1200	0	1200

In this we began with the "initial solution" $x_1 = 0$, $x_2 = 0$, $x_3 = 3600$, and $x_4 = 3600$. Next, we computed the changes involved from changing the initial solution by adding 1200 of screw 2. Since we are adding 1200 of screw 2, we enter it directly in its appropriate position in the change row. Then we multiply the 1200 by each of the entries in the column under x_2 in Table V. Each number so computed is entered in the appropriate space in the change row. That is, the number, 3600, which was computed by multiplying 1200 by the 3 under the x_2 column in Table V and at the intersection with the x_3 row is entered in the x_3 space of the "change" row. We do the same for the number 2400 which was computed by multiplying the 2 under the x_2 column at the intersection with the x_4 row, but enter it in the x_4 space of the change row. Each such product, for example 1200 x 3 = 3600, determines the amount of screw 3 or 4 (idle time) excluded from the new solution. It is recalled this amount of screw 3 is excluded from the new solution because for every one unit of screw 2 we produce, we eliminate 3 units of screw 3. Similarly, 1200 x 2 = 2400 units of screw 4 are excluded. The new current solution is obtained by adding or subtracting, as appropriate, the numbers in the change row from the previous solution row. The balance appears in the new current solution row. The profit at this step in the solution is, of course, the number of units produced times the unit profit: 4 x 1200 = 4800.

We must get ready for proceeding from point I to point J in order to improve further the profitability of the solution. Where previously we had production of 3600 of screw 3 and 3600 of screw 4, we now have 1200 of screw 2 and 1200 of screw 4. The composition of the production program at the initial solution, it is recalled, was indicated by the x_3 and x_4 located in the left hand column headed "S." Now, in the next computational table, x_3 will be removed from the solution column because x_3 has been replaced by x_2 in the solution at this step.

From Table II we can state that if we produce one unit of screw 1 we will exclude capacity to make 2 units of screw 3 on machine 1, plus capacity to make 5 units of screw 4, on machine 2. Since screw 3 is not made on machine 2 and screw 4 is not made on machine 1, we can write $x_1 = 2x_3 + 5x_4$

Similarly from this table we can write for each other screw

$$x_2 = 3x_3 + 2x_4$$
$$x_3 = x_3 + 0x_4$$
$$x_4 = 0x_3 + x_4$$

Now, if screw 2 is brought into the solution column at this step in place of screw 3, the bare table would be

	x_1	x_2	x_3	x_4	C
x_2	.....	.....	.....	.....	1200
x_4	.....	.....	.....	.....	1200

In order to carry out the next step in the computations we want to fill out the entries in the table. To do this we want to find similar equations for the x's in the top row, but now in terms of the x's which are in the solution column along the left side. To do this, we solve for x_1, x_2, x_3, and x_4 in terms of x_2 and x_4 (instead of x_3 and x_4 as they were in Table VI). This step is carried out as follows:

take the equations from Table II,

$$x_1 = 2x_3 + 5x_4$$
$$x_2 = 3x_3 + 2x_4$$

and solve for x_1 and x_3 in terms of x_2 and x_4, as follows:

$x_3 = x_{2/3} - {}_{2/3}\,x_4$ and $x_2 = x_2$

$x_1 = 2\,(x_{2/3} - {}_{2/3}\,x_4) + 5x_4$ $x_4 = x_4$

$x_1 = {}_{2/3}\,x_2 + {}_{11/3}\,x_4$

These equations have the same significance as those derived from Table II and, hence, we can enter the coefficients in them into Table VII as follows:

TABLE VII

P ⟶		3	4	0	0	C
	S	x_1	x_2	x_3	x_4	
4	x_2	2/3	1	1/3	0	1200
0	x_4	1 1/3	0	−2/3	1	1200

Step III: This step is identical to the preceding step and is summarized as follows in Table VIII.

TABLE VIII

P ⟶		3	4	0	0	C	A
	S	x_1	x_2	x_3	x_4		
4	x_2	2/3	1	1/3	0	1200	+1800
0	x_4	1 1/3	0	−2/3	1	1200	+ 327
w ⟶		3−(2/3 + 1 1/3 .0) = 1/3		0−(1/3 − 2/3 .0) = −1/3			
		x_1		x_2	x_3		x_4
Previous solution		0		1200	0		1200
				−2/3 x327	0		−(1 1/3 x327)
Change		+ 327		= −218	0		= −1200
New solution		327		982	0		0

Step IV: Inasmuch as we solved this problem graphically, we know already that we have achieved the optimal solution. However, in the more general case, we will not know this without a final step which will tell us that the solution at that step was optimal. This step is a repetition of earlier steps is as follows:

Use: $x_1 = {}_{2/3}\,x_2 + {}_{11/3}\,x_4$

$x_3 = {}_{1/3}\,x_2 - {}_{2/3}\,x_4$

to determine x_3 and x_4 in terms of x_1 and x_2

$x_4 = {}_{3/11}\,x_1 - {}_{2/11}\,x_2$

$x_3 = {}_{2/11}\,x_1 + {}_{5/11}\,x_2$

P ⟶		3	4	0	0	C
	S	x_1	x_2	x_3	x_4	
3	x_1	1	0	−2/11	3/11	327
4	x_2	0	1	5/11	−2/11	982
w ⟶		0−14/11 = 14/11		0−1/11 = 1/11		

Since there is no screw with a positive value of w at this step, there is no way to change the solution and achieve an improvement in profitability. Hence, this solution or program is optional. There is no better way, regardless of whether or not the method by which the program was developed is understood by the salesman who sells screw 1 or the salesman who sells screw 2. If there is any change in this production program, it will decrease profits. The only possible change that could improve profitability would be one that is based on some basic error, such incorrect profit accounting in setting up the problem originally. We are, indeed, at the highest point on the profit plane in this problem.

This type of representation and solution is, indeed, objective and scientific—once the basic facts have been agreed

* Those familiar with linear algebra and matrix theory will recognize these equations as equivalent to the following vector equation. (This familiarity is helpful but not essential at this point. Persons not so familiar will be introduced later.)

$$x_1 \binom{1}{0} + x_3 \binom{0}{1} = x_3 \binom{2}{5} + x_4 \binom{3}{2}$$

upon by the interested parties. In this case it has determined the "required quantity" in relation to an objective criterion, profit.

GENERALIZATION

We now wish to extend this method in several directions. We will do this only by indicating how the various conditions can be incorporated into the preceding computational technique. We will not give mathematical proofs, but concern ourselves with recognizing real-world problems and placing them in such form that we can solve them by methods already proven by mathematicians.

(a) Programming over time

The basic model presented in the introduction will handle this problem adequately simply by including the superscript time periods. There are, however, certain additional conditions which it may be necessary to observe. For example, it is noted that the model implies computing the load by machine tool (or machine tool type) by period. If there is an interdependence between production in one period and production in another, this must be included as a restriction. For example, it may be necessary to use the output of one period as the input of the next, a fixed amount of raw material may be available for allocated use over several periods, etc. Suitable restricting equations or inequalities can be developed to handle these.

(b) Material Allocation

If we have any raw or semi-finished materials in stock which can be used in two or more different end items, we have potentially a problem in determining how the material will be allocated. This problem can be handled easily by a set of restricting inequalities in which the coefficients, b_{ik}, indicate the amount of raw material k required in the production of one unit of item i, etc., for C_k.

(c) Alternative Production Methods

The most profitable program is not necessarily the one which uses only the "cheapest" method for every commodity being produced. Such program may entail, rather, use of alternative, and more costly, methods. Failure to use alternatives may result unnecessarily in delayed deliveries, loss of sales, loss of goodwill, etc.

This problem can be handled by including profit estimates in the objective function which reflects both the loss of revenue from delayed deliveries and the extra cost of using the alternative methods.

Accountants have failed to recognize this concept in their reporting and analysis methods. Their result often is to cause operating personnel to conceal or restrict their use of alternative methods, when, indeed such would be the most profitable thing to do.

If the problem involves questions of loss of goodwill, it is necessary to obtain numerical values for this loss. This can be done by using estimates obtained by "forcing" the general manager responsible for the firm to reveal the amounts he would "pay" for avoiding specified late deliveries. The values so obtained then can be used directly in the objective function.

(d) Inventory Costs

"A thin stream of swiftly flowing inventory with a high level of machine utilization" is one qualitative description of the optimal in-process inventory policy. It can be computed numerically with the methods discussed here. It is necessary only to attach appropriate costs to material in storage, to include appropriate restrictions on amount of material which can be stored due to financial limitations, space limitations, or other.

(e) Economic Lot Size

It has generally been recognized that the amount to produce as determined by economic lot size is not necessarily the most "economic." This fact is now explainable because these formula consider lot size only in relation to the profitability of that item alone, rather than of all items simultaneously. However, the linearity assumption of the model presented here is unrealistic in a problem in which there are strong non-linear relations in unit cost of production as a function of quantity.

The two alternative methods for determining quantity to be produced in a lot can be combined as follows. Compute the economic lot size and a range about that size over which unit cost is equal to or less than, say 110% of minimum. Then, in the computations in the method here, restrict the amount of each commodity to a value which lies within that range.

(f) Fixed Sales Requirements

If the minimum amount of production of any one or more items is predetermined (that is they simply "must" be produced), it facilitates computation to change variables so as to account for this requirement and eliminate this restriction from the computational problem. For example, say the amount of

$$x^t_i \geq d^t_i \quad , \quad d^t_i \geq 0$$

then we could write

$$x^t_i - y^t_i + d^t_i \quad , \quad y_i \geq 0$$

Substitute the variable $(y^t_i + d^t_i)$ for x_i in the objective function and the restricting inequalities and proceed as before. This effectively adds at least $d^t_i \times a^t_i$ to the profit and subtracts $d^t_i \times b_{ik}$ productive hours from the available capacity of the k*th* machine tool during the t*th* period.

This method may bring to light many incongruous situations wherein the "must" production is greater than the available capacity. The existence of this condition would be made apparent by the "must" production violating the capacity restrictions.

(g) Cost Minimization

If we have a problem in which the final bill of items is determined, the objective function becomes cost minimization. In this case, we would invert the computational procedure by taking as given the quantity of each item to be produced and then selecting the combination of equipment and methods which will produce these with the minimum cost.

(h) Profit Accounting and Marginal Costs

Generally speaking, accountants are not trained in mathematics beyond the principles of arithmetic and the algebraic methods of interest and annuities. Indeed, however, they are responsible for evaluating performance of operating personnel in several regards, for data analysis in managerial decision making, and of many other important functions.

Vatter already has pointed out some of the proper methods of data analysis for managerial accounting. Additional ones become available when one views the managerial decision through a mathematical model.

The standard costing as practiced is usually based on fallacious notions. It penalizes often where penalties are not due; it evaluates against an incorrect concept.

Variations from standard cost have no unfavorable meaning unless they are due to an act or event which reduces profit, rather than just increases cost. If an alternate machine tool, substitute operator, substitute material, or other is used in place of that on which the standard was determined, it may have been quite appropriate. The only method of so determining would be to reconstruct the situation as it existed at the time of the decision to use the alternate was made and then make a computation of the type indicated in this paper to determine if the best decision was made. But, this best decision probably would be achieved only if this type of computation were made.

The consequences of this philosophy are, indeed, significant. It could lead to the concept of "profit accounting" instead of "cost accounting," such that all levels of executive decisions would be evaluated against profit rather than cost. This would tend to give operating personnel objectives more consistent with the objectives of their firm. Of course, before this could be done, it would be necessary to adopt considerably revised analysis and reporting procedures in lieu of present cost procedures. This would depend, of course, upon adequate training and facility in methods such as those discussed here.

Depreciation and overhead were not included in this formulation. The reason is that, generally, these are sunk or fixed costs. The objective of the firm is to maximize revenue over expenditures at

each point in time, and hope that in the long run this will assure its existence into perpetuity by recovering sunk costs and making replacements possible. If these sunk costs are included in the determination of the profit used in the model, it would indicate only whether or not at that particular time they are being recovered by prices and production. If they are used in the computations for determining whether or not an item should be produced, this would be incorrect.

A preferred profit accounting approach should be to consider only variable and semi-fixed costs as charged against revenue in determining what and how many commodities should be produced. The semi-fixed costs can be introduced easily by penalties charges for using equipment or facilities above given levels of activity. Indeed, it is possible to include in the maximizing function both the prices and the variable and semi-fixed costs. However, it is usually easier to compute the net profit before commencing the programming computations. (We avoid here attempting to define "profit" beyond "excess of current income over current outlays for variable and semi-fixed costs." Persons having a different word for this definition may insert theirs at every point where "profit" is used in this paper.)

LIMITATIONS

As the size of any computational problem increases, the solution time required increases rapidly. Hence, there are important restrictions on the upper limit of the size of any problem. Of course, a large scale electronic computer is invaluable in handling these problems and increases their dimensions. In addition, any practical problem will have, undoubtedly, many features which will permit abbreviations in the computational method, and hence, reduce the time and cost of solution. The largest problem of this general type known to have been solved was 192 x 192. It required 47 hours on the UNIVAC. Rectangular problems with not more than 192 rows and with a much larger number of columns could be handled in approximately the same or less time. Smaller problems, of course, often can be handled in a matter of a few hours by hand or minutes by large scale computer.

"COLLECTIVE BARGAINING: NEGOTIATIONS AND AGREEMENTS,"
By Selwyn H. Torff,
McGraw-Hill Book Company, Inc.,
New York, 1953
323 pages, $5.50

Mr. Torff's book is a broad discussion of the contemporary features of labor-management relations. He covers both sides of current issues with reasons for the positions taken. Specimen clauses are included to show representative solutions. The author also discusses the legal aspects of labor relations, the grievance procedure and arbitration.

ELECTRONICS—A USEFUL TOOL FOR TIME PROBLEMS

(Continued from page 5)

ments or cycles. An important advantage of this equipment is that the original data is available for any statistical analysis which might be desired.

The actual timing by the electronic machine is done by the accumulation of pulses in decade counters. These are so arranged that the last counter which would normally carry over into another decade, is fed, instead, into a read-out machine. The read-out machine is a modified adding machine which forms a mechanical extension necessary for the printing and adding the accumulated electrical pulses.

At the end of a period which is being timed, a trigger pulse initiates a scanning circuit which converts the stored information in the counters to decimal information in the read-out machine. The read-out machine totals the pulses received from the electronic counter as well as the values accumulated in the counter decades and prints the total information in decimal seconds on an adding machine tape. It also resets all the counters back to zero automatically. (See the block diagram.)

The read-out machine operates at a rate of 180 cycles per minute, or ⅓ of a second per cycle. Therefore, sufficient time must be allowed for the scanning operation to be performed by the machine. A safety factor is applied such that the total time required for scanning and printing is approximately one and a half seconds. Where successive elements are less than one and a half seconds in duration, two read-out machines would be required. The power requirement for the entire unit is approximately 150 watts on 60 cycle, 115 volts A.C. The cost of the equipment is a function of the number of decade counters and the number of read-out machines. It is estimated that a unit with four decades and one read-out machine would cost between $2000 and $2500.

The use of this type of electronic equipment for time measurement problems has many advantages. It provides a permanent, accurate record of any operation whether for research or industrial usage. It is extremely simple to apply to any operation where microswitches or photocells can be inserted into the operation. For example, a photocell could be placed across a bin, such that each time the operator reached into the bin he would make or break a circuit which in turn would start the counter accumulating pulses of time. The time values are printed in decimal seconds, and each element within each cycle is identified. It provides an excellent opportunity to do performance rating since the observer does not have to do any manual work. It also provides extended opportunities for research work in performance times.

Point Toward A Goal

(Continued from page 8)

waiting for the man ahead to move up or out.

Years ago I asked my Dad, "How did you get into engineering?" His explanation seems to make my point. "Well, Son," he said, "I was night trick telegrapher at Lorain. The job ahead was day trick operator. That paid $5.00 more a month and the man holding the job was young and healthy. The job beyond that was dispatcher in Cleveland. That paid $5.00 more than day trick telegrapher. But the dispatcher was young and healthy. So I quit. I went to Toledo and got a job carrying a rod (not a gun) that paid more than the dispatcher's job in Cleveland."

If a man has prepared himself, many times he can make his own opportunities. His rate of progress may be limited only by his ability to assume added responsibilities gracefully.

WHAT IS SUCCESS?

But what is Opportunity? What are you seeking? More money? Bigger titles? What is Success? A new Cadillac every year? A ranch house with spring-fed swimming pool?

We say, "Gee, George sure got a lucky break. He's got a fine job, makin' a barrel of money." That's all right for George. Would that job have been good for you? Are you looking at George's job or his pay check?

We hear about this and that prominent success passing away. "He was so young too." Remember that some have to go early to hold down the average age. And we read a lot these days about "executive ulcers." That too may be misleading. With our marvelous advances in medicine, there are few diseases left to get sick with.

Joking aside, could it be that some of these men hurried too fast along a detour? Were they pushing themselves beyond their depths in fields that did not match their aptitudes and interests? Are they killed or sickened by "frustrations"?

It looks to me like we might have better luck by living to work rather than in working to live. That could come about more often if we used a better method than trial and error to choose our careers. My guess is that more people could be "happy" in industry if they knew better what work they should be doing. So I suggest that you find out whether you should point your course to the northeast or in some other direction. Make sure that you are on the main highway—not on a detour. Know where to turn to avoid the "construction."

The Validity of Basic Assumptions in Motion and Time Study

By Eugene Emerson Jennings

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In recent years industrial engineering has enjoyed a tremendous increase in acceptance and use in industry. Many principles and methods coldly received in the early stages of industrial engineering are today highly regarded in many quarters as proper if not necessary. Particularly is this true of aspects of industrial engineering commonly referred to as motion and time study.

There are several reasons why motion and time study has gained momentum. The huge increase in industrial capacity concomitant with increase in competition has required a more systematic evaluation of man-machine relations. Motion and time study evolved as a partial answer to this need in that it reflected a highly systematic method attempting to find the most efficient way of doing a job and how much work should be done in a given period of time.

Another factor contributing to the widespread acceptance of motion and time study relates to the demands that World War II imposed on man-machine relations. New machines were developed with less regard for the characteristics of the humans who operated them. The implied assumption was that the plasticity of the worker would allow unlimited adjustment to the requirements of operating machines properly. Machine demanding movement patterns contrary to generally accepted principles of motion and time study caused considerable frustration and inefficiency and contributed to focusing attention on operator's work methods and movements. In a limited way motion and time study counteracted attention given to machine design by affording opportunity to systematically study man's abilities and limitations.

The third reason for the increasing appeal offered by motion and time study relates to the present generation's tendency to be easily impressed by the term science and data apparently obtained under scientific conditions. To individuals easily impressed by simo charts, micromotions, and time recorded to 1/10,000 of a minute, motion and time study gives forth a scientific appearance. They easily confuse the meaning of science with system. The former necessarily encompasses the latter but a systematic method may not necessarily be scientific.

Motion and time study practitioners often deviate from the generally accepted method of science by not reporting their conclusions in the light and limitation of their implied assumptions. Huge quantities of data and statistics are gathered to improve upon this movement pattern or to measure the efficiency of this time element over another without pausing to reflect what assumptions are operating in each situation.

This error of omission may be partly justified because of demands for practical application which tend to limit interest and opportunity for proper research design. Furthermore, motion and time study has been a valuable tool in its present form to the extent that the necessity of adopting a more rigorously experimentally-controlled approach has been easily overlooked. The apparently practical value of improving man-machine relations offered by motion and time study, however, should not be construed to justify making unwarranted assumptions and, hence, unqualified conclusions.

The purpose of this paper is to review several basic assumptions generally implied in motion and time study. No attempt will be made to definitely prove or disprove their validity. Data thus far obtained under experimentally-controlled conditions are not sufficient for this purpose. However, as a counter balance to the present tendency to disregard these assumptions, data will be presented for the purpose of acquiring a questioning attitude. This kind of attitude represents an integral aspect of scientific method.

Probably the most pervasive assumption in motion and time study is that there is such a thing as an elemental motion with a universal time standard.[1]* Around this over-all assumption cluster many less pervasive assumptions that tend to manifest the basic assumption as being many and varied.

An elemental motion with a universal time standard involves believing that each individual motion in a total pattern of movement is a separate and independent unit. The total pattern of movement is composed of distinct motions measured in times which are summative in nature. Elimination of one motion reduces total time for the whole movement by an amount equal to the time supposedly required for the discarded motion.

This viewpoint commonly referred to as the atomistic concept of human behavior originates in an engineering or mechanistic approach to the study of human phenomena. The inadequacy of the assumption that the whole is equal to the sum of its parts is raised by one study which had an original pattern of movement involving tapping six keys requiring a total time of 2.42 seconds. Eliminating two keys requiring 0.71 seconds should have, according to the assumption that the parts add up to make the whole, reduced the total time to 1.71 seconds (2.42—0.71). However, the actual time to perform the second sequence was 1.81 seconds. In the second study opposite results were obtained in that the elimination of some of the keys significantly reduced the time required to perform one of the remaining motions.

Another study attempting to investigate the relationship between travel time of reach and manipulation time of grasp and turn revealed that varying the distance of reach influenced not only travel time but also manipulation time.[2] In effect, increasing the travel distance four times increased manipulation time about 30 percent.

The writer attempted to determine if the converse were also true. Will increasing the required manipulation time also bring a corresponding change in travel time for reach? Door knobs varying in friction from seven ounces to nine pounds were used. The results show that as friction increases, the travel time for reach increases substantially. In most cases the subjects used reach to gather momentum with which to overcome the friction. There was a generally lessened travel time for reach in order to obtain a secure, firm grasp of the knob in preparation for overcoming the increased friction.

Barnes and Mundel report an experiment in which subjects picked up pins and inserted them into a hole the aperature of which varied.[3] The results show that time required to carry the pin from point of supply varied with the size of the aperature.

Another aspect of the study previously reported is that manipulation of simple grasping and turning differs significantly from grasping and pulling as far as time of manipulation is concerned.[2] Pulling movements produce a significantly longer travel time in successive motions. Travel time for pulling motions is about 32 percent greater than that for turning motions.

These and other studies seem to indicate that time required to perform a motion among other motions in a total pattern of movement will vary with preceding and following motions and will be substantially affected by conditions either directly or indirectly associated with it.

The assumption that movement is made up of atoms of motions which are independent and, therefore, additive is open to serious questioning. The evidence herein presented indicates that the whole may possibly be superordinate to its parts.

The assumption that there is an elemental motion with a universal time standard also manifests itself in the statement that extending the distance of travel does not substantially affect the efficiency of time of a motion. An experiment to test this assumption reported that "both the manipulation and travel aspects of motion may be increased in duration by as much as fifty to seventy-five percent by a four-fold increase in the distance of the travel component of

* References listed by number at the end of the article.

the motion."[2] Thus the pattern of manipulation and distance of travel show integrative affects related to all of the components of the working task. "It must be concluded that any task involving a series of movements will be integrated into a whole by the worker and that each component movement may interact upon and affect every other movement."[4]

The assumption of an elemental motion with a universal time standard often evidences itself in the assertion that less complex movements are more efficient. One study reveals that variations in complexity of movement with respect to the number of directional dimensions does not produce substantial changes in efficiency of manipulation and travel components of movement.[5] In effect, efficiency is not definitely related to the complexity of a movement with reference to directional changes as an aspect of complexity.

Another aspect of the assumption that there is an elemental motion with a universal time standard is the statement that "motions should be confined to the lowest possible classifications in order to reduce fatigue."[6] In effect, of the five classifications of motions, finger motions are most preferable. One study investigating the motions involved in the simple task of tapping found wide differences in ability to tap ranging from 1.5 to 5 taps per second.[7] However, the highest tapping rate is obtained when most of the arm is used, either completely freely or at least with the whole arm from the elbow. In effect, people cannot usually tap as fast when they use only wrist motions and tapping is even worse when only the fingers are used.

This study also sheds light on the existence of an elemental motion with a universal time standard in that it reveals that tapping rate is not particularly stable. It can be changed by noise, and attitude influence. All of these conditions are present in variable amounts in the actual work situation. Although it is difficult to determine if the data on tapping have any relationship to other pattern of movements, it would seem logical to assume that similar patterns of movements might be affected by these variables.

Probably one reason for assuming that the lower classification of motions are most preferable is that they require the least time. In most instances when a number of motions are being compared, that which required the least amount of time is usually preferred. Although the quickest motion may be the most productive, is it the most efficient over a long period of time with respect to fatigue?

One study reports the fact that it takes practically as long to move your hand 5 inches and back as it does to move 15 inches. "If the distance is small, the hand accelerates more slowly than if the distance is great."[7] Very little time is actually saved by shortening the distance of the movement.

The writer found similar results in the door knob study previously mentioned. In this situation as different from that mentioned before, the knobs had equal amount of friction. The subjects stood at varying distance from the knobs from 36 inches to 6 inches. It is interesting to note that neither the travel time of reach nor time of manipulation for grasp and turn was substantially affected by distance.* A similar result is reported by a group who found that as the subjects reached farther for the knob, there was surprisingly little loss in turning time.[8] In the writer's study the results also show that the subjects obtained the best rhythm reaching approximately the distance equal to placing the palm of the hand flat against the knob with the arm almost completely straight. The distance in actual inches varied with each individual's height and arm length. Generally, the distance by this standard was between 23 and 26 inches which is longer than that reported as a desirable area within which to work.[9]

In a hurry to improve upon present motion and time study methods some practitioners have leaped from one method to another without a thorough understanding of the first method. As a result, in their attempt to alleviate certain problems they have created others just as serious. Synthetic time standards method is a case in question. The assumption of an elemental motion with a universal time standard is an integral feature of synthetic time standards. "The procedure is simply one of determining the motions required to perform the operation and then of assigning predetermined time standards to each limiting motion. The sum of the motion times gives the productive standard for the job."[10]

In short, this is a blown-up application of simple motion and time study method. The relationship among elemental motion in a complex movement pattern is assumed to be independent and additive in nature. Because of this, synthetic time standard practitioners have universal time standards for each elemental motion regardless of its position in a total pattern of movement and context of working conditions.

How can there be such a thing as predetermined motion time standards if the relationship of motions to each other is not definitely known? This question was uppermost in the minds of two researchers experimenting with a series of motions consisting of transport empty from a starting point, grasp and turn knob 30° and release, and return to starting point.[11] The conditions under which the motions were performed were changed systematically.

The results indicate distinct differences in the times for each motion in the pattern of movement for the different changes. A change in the pattern of movement relative to one motion significantly affected the time of the total sequence. Furthermore a change in one motion significantly affected the time of the surrounding motions.

The researchers suggest that the attempt to determine a universal time standard for elemental motions is unsound and that the collection of data for an elemental motion would be subject to adding errors upon errors. "The application of the collected data could not be accurate because the analyst could not determine what effect the particular job conditions would have as an elemental motion.[11]

Synthetic-time standards also seem to deny the possibility that a simple motion requires different times with respect to vertical and horizontal planes of movement. For instance, most people can usually tap slower up and down than sideways[12] but the time allowed would be the same under synthetic time standards. There is some data to indicate that a simple transport empty toward the body is naturally slower than away from the body.[13] These horizontal patterns of movement show a slower travel time than vertical movement patterns and that within vertical patterns of movement, downward directions of motion are faster than upward.[14] Synthetic-time standards based on predetermined time standards

* Note: This result may seem to contradict other studies previously mentioned with respect to travel time. However, in the present study travel distance is varied not only with regard to reach but also position of body. In this respect the two studies are dissimilar.

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are not sensitive to these potential variations in characteristics of elemental motions in patterns of movements.

The research data presented are inadequate for supporting a definitely positive or negative position with respect to the validity of the assumption that there exists an elemental motion with a universal time standard. However, evidence is strong enough to command at least a more cautious approach to the study of human behavior via motion and time study. A questioning attitude is recommended regarding the possibility that the whole pattern of movement is necessarily superordinate to the sum of its motions. Perhaps rather than the whole being the sum or synthesis of its parts, it is their sum plus their interrelationships. Any task therefore would represent an integrated whole whose characteristics vary according to change of any of its parts or conditions of activity.

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THE WORK SIMPLIFICATION FORMULA

(Continued from page 6)

ponents is emphasized by their position in the work simplification formula.

I have intentionally attempted to mislead you by the title of this article. I hope you now realize that successful Work Simplification cannot result from a blind application of a mathematical expression of analysis technique. Successful Work Simplification requires utmost consideration of the Human Factor, and a mutual cooperation between employees and management in order to achieve mutual benefits. Let our formula help you remember the relationship—

$$SWS = (PWS + tws)^{HF}$$

THOSE ANNOYING "HUMAN FACTORS"

(Continued from page 4)

source of his frustration has been eliminated, no matter what corrective devices may be employed.

This finding has far-reaching implications for the handling and motivating of employees. Frustration may originate either on or off the job. In either case, efforts to improve an employee's performance are likely to be wasted effort until the frustration has been eliminated. Some plants have recognized the importance of this fact by making counseling services available to help resolve family and other off-the-job problems. Penalizing or haranguing frustrated workers who repeatedly "gum up the works" can be expected to make the situation worse rather than better. The supervisor as well as the employee is likely to become frustrated; other employees are liable to become nervous and work under pressure as well. Again, changing work patterns tends to have a negative effect.

11. Opportunity to make decisions and to use initiative contribute to job satisfaction and provide incentive.

Most Americans want to feel that they have something to say in determining their own behavior. The concept of democracy which the average worker brings to his job necessarily conflicts with the centralization of decisions which prevails in most plants. Most executives would object that the factory is no place for democracy—that you can't make business decisions by a show of hands. Many would add that their plans are none of their employees' business anyway.

In specific areas this is unquestionably true. In many other areas it has proved possible to employ a republican approach, however. Some plants have successfully adopted a system of having employee deputies meet monthly with management appointees. In large organizations this may be done at all levels. Any topic is open to discussion. There are two possible stumbling blocks: convincing employees that they can speak freely on any subject without fear of penalty, and the need of having management representatives who can handle the tough assignment. The plan has been extremely successful in plants where it has been tried. Employees have an opportunity to air complaints. Misunderstandings can be eliminated; others can be prevented. Valuable employee criticisms and suggestions can be channeled directly to management. Employees and management representatives have an opportunity to know each other as persons, eliminating ignorance which tends to cause conflict. Employees develop an appreciation of planning problems, and often come out with a new and healthier perspective on their own jobs.

12. Job satisfaction depends more on employee-supervisor relations than on any other factor.

This relates directly to several previous items. The supervisor is a primary source of support for one's self-esteem and of emotional security on the job, for example. An employee may like his work, be satisfied with his earnings, enjoy the physical surroundings, have a high regard for the company he works for and still gripe about his job if supervision is unsatisfactory.

These are some of the human factors that are likely to affect the industrial engineer's work. It may be impossible for him to incorporate such variables into his design. If so, trouble can be expected. It may be possible for the industrial engineer to secure sufficient training in the social sciences to enable him to include these human factors in his analysis. If not, collaboration with social scientists may prove feasible, at least in the design of instruments capable of securing data vital to the successful completion of his design. From the social scientist's point of view, it is encouraging to learn that the industrial engineer is concerned about the human factor. More scientific research on practical problems by professionals in both fields should make it possible to prevent further "bindery" fiascos. And it should relegate industrial engineering's "Achilles heel" to the realm of mythology, where it belongs.

Book Review

"Elements of Radio"
Third Edition,
by Abraham and William Marcus,
Prentice-Hall,
New York, 1953, 771 pages, $6.00.

This popular work will be helpful in supplementing the average industrial engineer's education in radio and as basic reference work in the radio field. It has been revised to include the latest developments. The authors' method of combining a simple theoretical explanation with the practical application will appeal to many engineers. Although few formulas have been included, the large number of diagrams aid easy visualization of the principles.

TIMESTUDY TRAINING AIDS

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Industrial Engineering As An Occupation*

By Wyllys G. Stanton, P.E.

Professor of Industrial Engineering, The University of Alabama

WHAT IS INDUSTRIAL ENGINEERING?

It is one of the newer branches of the engineering profession whose members engage in the application of engineering methods, art and science to problems of industrial production, organization, management and similar fields.

HOW DOES ONE ENTER INDUSTRIAL ENGINEERING?

Usually by studying for an engineering degree in one of the 41 colleges or universities that grant degrees in Industrial Engineering or as an Industrial Engineering option in some other degree granting department, which have been accredited by the Engineers' Council for Professional Development.

It is also possible to enter the field after obtaining a degree in some other branch of engineering by obtaining employment in Industrial Engineering work. Some men qualify n this field without formal engineering education by obtaining employment as aids or assistants to Industrial Engineers and pursuing courses of home study. It should be recognized, however, that this road is becoming increasingly difficult in competition with men who have full training.

WHAT ARE THE ENTRY OCCUPATIONS IN I.E.?

Upon graduation young Industrial Engineers usually obtain employment with large companies where they may be assigned to:

Engineer Training Programs
Time and Motion Study Departments
Plant Layout Departments
Production Control Departments, etc.

HOW DOES AN INDUSTRIAL ENGINEERING CURRICULUM DIFFER FROM OTHER ENGINEERING CURRICULA?

The courses taken by I.E. students at most accredited institutions are of three types. First, there are the courses required of all engineering students regardless of branch; chemistry, mathematics, physics, engineering drawing, English, and mechanics. Often there is little or no difference between the curricula in the first year, and not much in the second year. Secondly, there are courses that are basic to all engineering, and which begin to differentiate the engineering students from other students. In this area engineers take courses in branches other than their own, in order to have a sound foundation in engineering in general. For example, the mechanicals, civils, and industrials take courses in electrical circuits and machinery; the civils, electricals, and industrials take courses in mechanisms, heat engines, etc. During the last two years students of each branch specialize in their respective fields and take most of their work in their own departments.

WHAT ARE THE SUBJECTS STUDIED BY INDUSTRIAL ENGINEERS DURING THEIR PERIOD OF SPECIALIZATION?

There is some variation between different accredited colleges, but in general they all study the material of the following courses, although the course titles may vary.

Time and Motion Study
Industrial Organization
Safety Engineering
Quality Control
Accounting
Wage Incentives
Material Handling
Production Control
Industrial Management
Factory Planning
Statistics
Job Evaluation
Industrial Structures
Engineering Economy, etc.

WHAT ARE THE FUTURE PROSPECTS FOR INDUSTRIAL ENGINEERING GRADUATES?

All engineering graduates are in great demand, and according to the studies of the Engineering Manpower Commission, this condition is likely to continue for many years. Ours is a Civilization based to an ever increasing degree on the work of engineers.

Engineers are progressing to top executive positions to an extent never before anticipated. In 1946 a study by Mr. Walter Evans, Vice-President of Westinghouse showed that 50 of the 150 largest corporations in America had graduate engineers as their presidents. In 1952 a survey by the National Society of Professional Engineers revealed that 70% of 3,500 plants reported use of graduate engineers for non-technical work including executive duties outside of the engineering departments. Industrial Engineers are particularly well fitted to progress to such executive positions.

Industrial Engineers may remain in staff work, where there are many very fine positions in both large and small companies, or they may go into line jobs and progress in supervision. From the start the work of the I.E. is likely to take him into all departments of a business and afford him excellent opportunities to know the work and the people of his company.

WHAT IS THE DIFFERENCE BETWEEN INDUSTRIAL ENGINEERS AND GRADUATES OF CURRICULA IN INDUSTRIAL MANAGEMENT?

Although there is some similarity, particularly in the fact that the industrial management curricula includes some of the same subjects as are studied by the Industrial Engineers, there is the great difference that the Industrial Engineers **are first of all engineers.** The men who have studied Industrial Engineering are trained in the engineering method and are prepared to work in close co-ordination with engineers of other branches. Although they have studied accounting, economics and some other topics which might be considered primarily the field of business administration students, it is for the purpose of applying the techniques thereof to engineering manufacturing problems. Industrial management courses are almost always taught in colleges of commerce, and while the instruction may be very good, it is not in an engineering atmosphere.

WHAT HAS BEEN THE GROWTH OF THE INDUSTRIAL ENGINEERING PROFESSION?

The increasing industrial development of the country has caused an amazing growth in this field. Prior to the 1940 census, Industrial Engineers were not reported separately, so it is impossible to know how many there were in the country. In 1940 just under 10,000 persons reported their occupations to be industrial engineering, and in the 1950 census this group had grown to 46,700, an increase of 376%. The next greatest growth was made by the Chemical Engineers who increased 168% and the oldest branches of engineering had increases in the same period of 15 to 18 per cent.

DOES INDUSTRY RECOGNIZE THE INDUSTRIAL ENGINEER?

Since the time when Frederick W. Taylor, the first great industrial engineer, did notable work for the Bethlehem Steel Company about 1890-1900, the services of men trained in this work have been widely employed in all types of industry. However, at the present time industrial recognition is greater than ever, and increasing. The following are some of the companies having departments of Industrial Engineering:

U. S. Steel Corp.
Armstrong Cork Co.
Republic Steel Co.
Aluminum Co. of America
Ford Motor Co.
Owens Illinois Glass Co.
North American Aviation Co.
McWane Cast Iron Pipe Co.

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* This statement is written to provide a simple explanation for students contemplating a career in Industrial Engineering. It is not expected all I.E.'s will agree with all the statements made.

Time Standards and Methods Changes*

By MacRae H. Curtis,

Plant Manager, The Charles Parker Co., Meriden, Connecticut

The progressive management today is very aware of the vital necessity for reducing costs.

The lush days of "accepting orders" is over and the company that will stay in business will be the wide-awake company—wide-awake to every possibility of cost reduction.

The answer to this is not necessarily the spending of a lot of money for new machines and equipment. Too often, the average sized company does not have that kind of money available. Instead, there are many benefits to be obtained if existing methods and processes are subjected to a systematic and searching analysis. Such benefits very often exceed those which would result from the purchase of machines and the cost of obtaining these is negligible compared to the results.

So, we must recognize the need for good sound methods engineering either by methods engineers trained for such work and/or by intelligent shop supervisors.

The well trained supervisor can be of considerable assistance to the methods engineer and can play an important part in the selection of the final best procedure when setting up operations. For this reason it is essential that those in charge of such manufacturing operations have a good fundamental knowledge of methods engineering and methods improvements.

We must remember that this will be very helpful in the training of the operators. His constant association with correct methods and procedures results in quicker acceptance of the right way to do things. He soon demonstrates his ability to absorb the principles of motion economy if it is practiced religiously and faithfully by the supervisors.

Ralph Barnes once said that the ingenuity, ability and ideas of foremen, supervisors and workers are among the greatest untapped resources of this country. He pointed out that the day had passed when the top executives in the front office were supposed to have all the good ideas. How right he was! But, too often this is completely overlooked and one of the best sources of reducing costs and improving your position against competition has been lost.

So, there is no question of the value of a good methods and standards program that insures the best possible set-up of operations in the plant, efficient and methods-conscious supervision and a Standards Department trained in motion economy and use of standard data in one form or another.

However, our work is far from being over. Many a plant manager at this point has felt secure with such a program and yet has awakened with a bang one day to realize that, in spite of all the scientific procedures being practiced and used, the time standards in his plant were up to 20% loose.

This is not unusual as indicated by the following: A highly regarded industrial engineering firm recently made a survey of 316 manufacturing companies that showed that 78% of the wage incentive plans had failed or developed major weaknesses.

An analysis of this high percentage of failures showed that there were nineteen basic reasons for such failures, and third on the list in importance was "methods changes not coordinated with standards." This firm also commented as follows: "Technological change amounts to 2½% to 3% each year. That is 25% to 30% over a period of 10 years. This technological change is gradual and continuous and not extremely radical. Therefore, many management men and industrial engineers do not recognize this constant productivity improvement as it takes place. Often it is overlooked until it is too late and the adjustment of standards is too great to be assimilated and accepted by the employees. Standards *must* be tied to the current methods of operation."

So, as a matter of factual record, many managements are not even aware of weaknesses in their incentive plans.

What we can do about it? Well, there are several things to do.

First, it is important to invest the foreman with the responsibility of reporting all methods changes *promptly*. To do this he must be thoroughly conversant with the method that was used at the time the standard was set so that he will be alert to report the changes. The Standards Department must see to it that he is provided with all necessary specifications and information.

Management on its part must everlastingly drive home to its foremen the importance of reporting such methods changes and must be firm in its evaluation of foremen when this is not done. When a good job *is* done, it is important for management to recognize this via some method of bonus payment.

Second, it is necessary to include as part of the Standards Department a so-called "follow-up man." His job is to pick studies out of the file and check the present method in the plant against the method performed when the study was taken.

He also follows up tool changes. A copy of all requisitions on the tool room concerning tool changes is sent to the Standards Department. This keeps the department informed that changes in tools are about to take place and a new standard may be necessary. When the tool work is completed, the original requisition is returned to the Standard Department and the follow-up man checks with the foreman to ascertain when the next run will come through. This position in the Standards Department can be filled with a junior time study man. It gives him an excellent opportunity to thoroughly analyze the time studies taken by experienced time study men and is very helpful in developing the procedure on correct methods and manufacturing processes.

Third, it is very helpful to assign someone to analyze the information contained on the daily time cards. I submit to you that proper analysis daily by a well trained individual can accomplish miracles. This person can be the timekeeper or a clerk in the general factory office who can run weekly tabulations on individual employees by earned unit hour. Such a record discloses that a slow but steady upward trend in the case of individual operators is taking place.

If this proves upon checking to be a legitimate improvement, we are pleased indeed for increased output per hour is the all-important goal of every industry. But, many, many times it is *not* legitimate and the routine investigation reveals that a change in method has taken place without being reported to the Standards Department.

Next comes top management's role in this control program.

For one thing, management must very definitely back up the work of the Standards Department. How often it has happened that management has made adjustments on standards to settle grievances with the union although in the process of doing so it not only has created an inequity between standards but has undermined the morale of the very men who are protecting the company's labor costs.

For another thing, management must follow a very definite policy in regard to the change in standard to correspond with the change in method. If management introduces a change in method and accompanies it with the corresponding change in standard, it is readily apparent to the operator as being a fair procedure. He has never had the opportunity of working with the old standard and

* Based on a presentation to the Management Conference, August, 1952, jointly sponsored by the University of Connecticut and the New England Chapters of S.A.M.

* (See Title Page for Footnote.)

the new method and the revision becomes a perfectly normal thing. Too often, however, through carelessness the change in method is not reported to the Standards Department and a cycle of loose time standards has begun. We *must* control this reporting if we are to have equitable standards.

Then we have the problem when the operator is the one to make the methods improvement. Now we have a difficult problem and if we deal with it carelessly, we are in for a lot of trouble. Too often, management allows a new time study to be taken and the time standard reduced without regard for the operator. And what happens? The human relations program goes out the window and management just had the last methods improvement from the operator they are going to get. Also, conversely, management allows the operator to keep the old standard as a reward for his progressive thinking and cooperation. Of course, this is wrong. The operator's earnings become abnormally high on the job and soon affects other operators on similar work. An inequity between standards now exists and all standards are out of line with each other. The soundness of the incentive plan has been affected.

The answer to this problem must be sought with one firm rule in mind:

"It is absolutely *mandatory* that the method is revised, *regardless of the amount involved.*"

This protects the equity between standards, that all important consistency, the core of a successful standards program.

But let's do something for the operator. Secure his cooperation by paying a proportion of the savings of a certain volume. Perhaps such a set-up exists now in your plant under a suggestion system. If not, you can start right now by establishing a policy that there will be a reward for the operator on every standard that is reduced as a result of the operator's suggestion. *And pay it promptly!* A lot can be accomplished here in good relations if quick action ensues when the improvement is noted. Conversely, the operator usually thinks you're trying to figure out a way to evade payment if any long delay occurs and thus much of the good feeling is lost.

If the fundamentals stated here are carried through to a conclusion and *maintained*, a long step towards correct time standards will have been taken and the company will be on a sound basis of labor costs.

Briefly:

1. Control costs by sound methods engineering and well trained supervision.
2. Tighten up the procedure for keeping standards abreast of methods changes by
   (a) The Foreman
   (b) The Follow-up Man
   (c) The Analyst.

   We know as a result of a factual survey that the success of our incentive plan is at stake if failure is acknowledged here.
3. Provide the Standards Department with 100% backing by top management.
4. Set up a policy for control of changes in standards corresponding with changes in methods by
   (a) Changing the standards when the method is revised *regardless of the amount involved.*
   (b) Set up a proper system of reward to the personnel for improvements.

There is no mystery in good control. It requires only a proper balance between intelligent aggressive thinking and the application of good common sense.

PRESIDENTS MESSAGE

(Continued from page 2)

AIIE. Each member helps to publish each issue. In addition, each subscription helps in a modest way. Advertisements also help. The costs of publication are all direct costs, with many hours of free labor and skill gladly donated to a most worthy cause.

How can you help? You can help the JOURNAL continue to grow and better serve you in the following ways:

1. *Write.* Let your reactions be known. Your suggestions will be very helpful. If you feel that a certain subject has not been receiving its fair share of attention, maybe something can be done about it. Maybe you disagree with some author and would like to write a discussion of his paper giving another viewpoint. Criticism, particularly constructive criticism, is very helpful.
2. *Submit articles* that you think would be of value to JOURNAL readers. If you do not care to write, then encourage others to do so, submit copies of papers presented to Chapter meetings if they are good, and suggest authors that could contribute.
3. *Help increase circulation.* Almost every company subscribes to Professional magazines. Ask your company to subscribe. Ask your friends to subscribe.
4. *Get ads for the JOURNAL.* Ask your advertising department how to get an ad. The rates are reasonable, and many organizations would be glad to be able to help out and to help themselves. Maybe you will want to discuss this with other members of your Chapter, and undertake a project. One ad from each Chapter would allow the JOURNAL to increase its size by almost 100%.

See you in Louisville, May 5, 6, 7, 8.

INDUSTRIAL ENGINEERING AS AN OCCUPATION

(Continued from page 19)

B. F. Goodrich Rubber Co.
Univis Lens Co.
Jeffrey Mfg. Co.
Westinghouse Electric Co.
Calumet and Hecla Corp.
American Locomotive Co.
U. S. Ordnance Dept
Cleveland Twist Drill Co.
Armstrong Tire and Rubber Co.
Blue Ridge Glass Co.
Bendix Products Div.
Boeing Airplane Co.
Buckeye Cotton Oil Co.
Standard Oil of Ohio

There are hundreds of others having Industrial Engineering departments. In addition there are hundreds of other companies that hire Industrial Engineers, although they work in departments bearing titles such as, Production Control, Plant Layout, Scheduling, Plant Engineering, etc.

WHAT ASSISTANCE IS AVAILABLE TO INDUSTRIAL ENGINEERING STUDENTS AND RECENT GRADUATES?

The American Institute of Industrial Engineers, 145 North High Street, Columbus 15, Ohio is dedicated to all activities that promote the improvement and development of this branch of the profession. Some of the activities include publications:

The Journal of Industrial Engineering
The A.I.I.E. Newsletter
Various Monographs

An annual convention is held for exchange of ideas and presentation of papers. Numerous National Committees study various aspects of Industrial Engineering work and the role and position of the I.E. as a professional man. There are 21 student chapters and 29 senior chapters. Members of all of these chapters are pleased to help those considering entry into the profession.

Book Review

"More Profit—Less Paper"
by J. W. Lucas,
Standard Oil Company of California,
San Francisco, California
1953, 59 pages, single copies free
(write to L. L. Purkey, Manager, Department on Organization, Standard Oil of California).

Illustrations are presented of practical methods and procedures for surveying and simplifying administrative, accounting, clerical, and other office detail. No attempt is made to provide answers to problems. The presentation is based upon actual experience, and the methods and procedures described have proven useful and effective over a period of many years in the diversified operations of the Standard Oil Company of California and its subsidiaries and affiliates. The purpose is to provide a step-by-step procedure by which a work simplification survey of office activities may be conducted.

◆ BOOK REVIEWS ◆

"Proceedings—5th Annual Industrial Engineering Institute"
University of California
Edited by D. G. Malcolm,
Published by The Elliott Printing Company, 1016 Jackson Street, Oakland 7, California,
1953, 120 pages, $3.00.

A complete reprinting of material delivered to the Berkeley and the Los Angeles sessions of the 1953 Industrial Engineering Institute sponsored by the University of California. Topic listings are: The Industrial Engineering Function in Medium Sized Business; Industrial Engineering, Planning and Control for Small Manufacturing Plants; Automation in Smaller Industry; A Case Study in the Relationship Between Design Engineering and Production Engineering; Time Reduction Curves; Mathematical Theory of Time Reduction Curves; Production Applications of Time Reduction Curves; Visual Inspection for Surface Defects; Accuracy in Reading Instrument Dials; A Study of the Additive Properties of Motion Element Times; A Statistical Analysis of Visual Inspection Methods; An Analytical and Graphical Solution for Some Problems of Line Balance; Research Developments of Quantitative Methods in Production; Analysis of a Cargo-Handling System; The Evaluation of an Electrical Artificial Arm Using Motion and Time Study Techniques; Discovery Sampling; Building Reliability into Complex Equipment Through the Application of Quality Control Procedures; Job Evaluation; Incentives for Indirect Labor; The Future of Industrial Engineering; Value Analysis—A Plant Wide Creative Cost Reduction Program Under Purchasing Leadership; The Application of Operations Research to Industry.

"Proceedings, Railway Systems and Procedures Association, 1953 Winter Meeting"
Railway System and Procedures Association, J. W. Milliken, Secy.-Treas., 30 Church Street, New York 7,
1953, 116 pages, $3.00.

The RSPA is an organization dedicated to assisting railroad management in realizing maximum effectiveness by promoting an awareness of improved ways of doing things. The Proceedings contain addresses directly in line with the organization's main objective. The Industrial Engineer will find that his tools and techniques are being used, and considered to be of great value, in the solution of some of the major problems in railroad operation. Some of the topics included in the Proceedings are: Early Reporting to C & O Top Management; Case Studies of Closing Techniques Used in Industrial Companies; Budgetary Control Plan of the Illinois Central Railroad; Evaluation of Information Handling Systems; The Prospect for Railroad Operations Research; Terminal Problems in the Pittsburgh Area; Some Examples of Operations Research Work.

"Management Controls—An Annotated Bibliography"
The W. E. Upjohn Institute for Community Research,
709 South Westnedge Avenue,
Kalamazoo 44, Michigan,
1953, 40 pages, single copies free.

A very useful source of information concerning management problems; both books and periodical materials are listed. The main topical listings are: Basic Material; Plans and Policies; Organization for Control; Management Audits; Operations Research; Check Lists; Management Reports; Outside Assistance; Appraising and Measuring Results; Company Systems of Control.

"The Man on the Assembly Line"
by
Charles R. Walker and Robert H. Guest,
1952, Cambridge, Massachusetts,
Harvard University Press,
180 pages, $3.25.

Although this is not an engineering study, the results and conclusions are important to industrial engineering. This investigation covering worker motivation, attitude and satisfaction was made by members of the Institute of Human Relations at Yale University. One hundred and eighty workers from an automobile assembly plant were questioned about their jobs and their attitudes toward their work.

With scientific restraint, the authors draw no sweeping conclusions nor do they make far-reaching recommendations. They did find that the large majority of the workers regarded the mechanically paced conveyor as an undesirable feature of the job, although the economic features of the job were satisfactory. They suggest that job specialization and break-down may have been carried to the point of decreasing returns.

Perhaps the industrial engineer can make use of the results of the study to improve output and increase job satisfaction. Even though the book may not be of immediate use, the authors have done a commendable job in their able investigation of the worker's view of his position in industrial society.

"Standard Costs for Manufacturing"
Second Edition
New York,
by Stanley B. Henrici,
Second Edition
New York, McGraw-Hill Book Company, Inc., 1953, 336 pages, $5.50.

In this revision of his widely used work on standard costs, Mr. Henrici retains the clarity and completeness which made the original edition so popular. He covers the theory and principles adequately, yet does not wander into the innumerable details of application. The basic principles of standard costs are not difficult for anyone with some accounting training. However, the successful use of standard costs in an operating enterprise requires a measure of judgment and experience which no written matter can provide. This book will give the reader a good background in the concepts and theory of standard cost.

Many of the changes, such as more review questions and problems, are of interest chiefly to educators. However, the author has expanded the chapters on labor and material standards and variances and has added a chapter summarizing standard-cost accounting procedures. These revisions will increase its usefulness to the reader.

"Metal Machining"
by Lawrence E. Doyle,
Prentice-Hall, Inc.,
New York, 1953, 511 pages, $10.00

Prof. Doyle has written an excellent book on a difficult topic. He has emphasized the uses and limitations of the metal machining processes from the engineering standpoint instead of discussing technical details which are meaningless without personal knowledge of the process and which are not useful except to engineers immediately engaged in the process itself.

In a work on machine processing, an author always has difficulty choosing what is to be included and what is to be left out. Prof. Doyle has done a noteworthy job in keeping the size of the book within bounds, yet including information of value to the most potential readers. In my opinion, his starting approach through tolerances and inspection is very good. The machining processes covered include lathe work, shaping and planing, drilling, milling, broaching, grinding, and related processes. The author also includes material on screw threads, gears, surface finishes, and a chapter on process planning.

"Case Studies in Collective Bargaining"
by Walter H. Carpenter, Jr.,
Prentice-Hall,
New York, 1953, 465 pages, $4.95

Mr. Carpenter's approach to collective bargaining makes interesting reading. The organizers of the SWOC, the argumentative steward and the foreman in a clothing plant, the foundry president with his strike strategy all come to life as principals in an industrial drama. Although general principles are discussed only briefly, the author's portrayal of the motives and actions of men give the reader added insight into labor-management relations.

"Survival Through Design"
by Richard Neutra
Oxford University Press
New York, 1954.
384 pages, $5.50.

From his experience as an architect and his broad education, Mr. Neutra advances the thesis that modern industrial products are poor in design because they are not suited to the biological and physical make-up of human beings. Unfortunately, his book is one of protest rather than one of positive approach. As a corallary of this attitude, there are no illustrations, a serious omission in any work on design. Thus the book has little practical or current significance, although it may be a forerunner of the industrial design ideas of the distant future.

"Elements of Radio"
Third Edition,
by Abraham and William Marcus
1953, New York, Prentice-Hall,
771 pages, $6.00.

This popular work will be helpful in supplementing the average industrial engineer's education in radio and as basic reference work in the radio field. It has been revised to include the latest developments. The authors' method of combining a simple theoretical explanation with the practical application will appeal to many engineers. Although new formulas have been included, the large number of diagrams aid easy visualization of the principles.

"The Theory of Inventory Management"
by Thomson M. Whitin,
Princeton University Press,
Princeton, New Jersey, 1953,
245 pages, $4.50.

Although the investigation upon which this work is based was primarily concerned with military inventories, much of the discussion is devoted to methods of control used by private industry and business. The author uses the theoretical and mathematical approach to inventory control, yet he includes many practical applications and some data. The formulas are presented in terms familiar to engineers although a few more advanced methods are used.

Although considerable space is devoted to requirements special to the military and to economic theory, this book has valuable material for the engineer who must consider inventories and their control as part of his job. This is easily one of the most comprehensive and useful works on the subject available today.

"Construction Methods and Machinery"
by F. H. Kellogg,
Prentice-Hall, Inc., New York,
1954, 415 pages, $10.00.

In this excellent work, Dean Kellogg applies industrial engineering ideas and methods to the construction industry. Because of small jobs, scattered locations and non-standard product, methods improvements have been slow in this field. The resulting book is a wealth of cost-saving methods in an area which touches upon almost every business. Dean Kellogg lays great emphasis upon the economic features of construction materials and techniques.

Although many Industrial Engineers have little to do with construction, those who do will find Dean Kellogg's book a valuable source of information on building methods and economics.

"Industrial Management in Transition"
Revised Edition
by George Filipetti,
Homewood, Illinois,
Richard D. Irwin, 1953,
Homewood, Illinois,
Richard D. Irwin, Inc., 344 pages, $6.65.

To those who want a comprehensive one-volume history of the scientific management movement, Filipetti's book is highly recommended. He outlines the major contributions of the pioneers, Taylor, Gantt, Gilbreath and others to the profession which has since become industrial engineering. In his eminently readable style, the author covers later developments in scientific management which have influenced management, labor and industry both here and abroad. The revised edition provides coverage of events since the publication of the first edition in 1946.

History of the American Institute of Industrial Engineers

Although our organization is still very young it is not a bit too early to start collecting and writing its history. In the years to come death and failing memories will shroud in even greater obscurity the record of the efforts and troubles of those who worked hard to develop this organization, their successes, failures and repeated trials.

Of course much information is to be found in the files of the national headquarters, but the staff operating there has its hands full in keeping up with day to day problems arising from the continued growth of the organization. Growth in membership and chapters and in services to the membership and the nation. Until such time as some patient researcher can be found to spare the hours necessary to dig into the records, that much of the history is locked away. Moreover, these records, which would naturally be thought of as the logical source of the history of the organization, have not proved to be as fruitful, in the brief inspections that have been made, as might be expected. This is because correspondence is generated with the objective of getting a job, such as organizing a new chapter, done as well and quickly as possible.

Fortunately there is another way. If each member who has participated in the growth and development would take the time to write a letter recounting his experiences, it would soon be possible to put these together in a coherent and interesting story. It is not necessary to be a skilled writer to participate in this work. Simple statements, such as "The first meeting of our group was held on _____ at _____ with _____ persons in attendance." or "Our committee was formed by appointment by _____ of the following men with a charge to _____."

The work has already been started, a skeleton history based upon the memories of some of the national officers is now being written, but there are many gaps to be filled in. Please write a letter to the undersigned at your earliest opportunity, telling all that you remember about your association with AIIE.

Wyllys G. Stanton
Chairman, History Committee
Box 427, University, Ala.

Review of Communication in Management

Communication in Management
(A Guide to Administrative Communication)
by Charles E. Redfield, Ph.D.,
The University of Chicago Press
1953, 290 pages, $3.75

Few executives today need to be "sold" on communication, but many have become preoccupied with its "gimmicks" rather than its essence. This is not hard to understand since "Communication" is an abstract and elusive entity. Dr. Redfield's book stresses that communication is not something to be disposed of in a specialist's office, but is continuously part of everybody's job. Its most severe difficulties reside in our deep-seated and subjective attitudes and in our daily person-to-person relations.

"Communication in Management" covers the nature of administrative communication; oral and written order-giving; manuals; reports; suggestions; interviews; polls; conferences; and finally its implication to organization theory; as well as many other items. It makes extensive reference to the literature of the field and presents a very useful approach to this vital area of management.

by Walter B. Schaffir
Staff Assistant-Administration
Sperry Gyroscope Company

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Fifth Annual AIIE Conference and Convention

The Kentucky Hotel — Louisville, Kentucky — May 5-8, 1954

***Conference Theme* — WHAT'S NEW IN INDUSTRIAL ENGINEERING?**

***Industrial Exhibits* — Open 9 A.M. - 6 P.M. daily, May 5, 6 & 7**

WEDNESDAY, MAY 5

Morning:
Registration
TECHNICAL SESSION #1—NEW CONCEPTS OF OLD PRACTICES
Topics—The Dynamics of Industrial Engineering
—New Uses of Early Standardization Systems

Afternoon:
Lunch—Topic, "The Louisville Story"
TECHNICAL SESSION #2 — NEW INDUSTRIAL ENGINEERING PRINCIPLES
Topics—Labor's Acceptance of New Standardization Practices
—Techniques of "Application Engineering"
—The 4th Dimension of Manufacturing
Social Hour

Evening:
Dinner—Topic, "Kentucky Industrial Progress"
AIIE CHAPTER OFFICERS' FORUM
AIIE NATIONAL COMMITTEES' MEETINGS

THURSDAY, MAY 6

Morning:
TECHNICAL SESSION #3 — NEW TOP MANAGEMENT TECHNIQUES
Topics—Management's Sixth Sense
—How Labor Looks at Management
—How Management Looks at Labor
—What Operation Research does for Management, Labor & Consumer

Afternoon:
Lunch—General Electric Plant
TECHNICAL SESSION #4—AUTOMATION IN OPERATION
G. E. PLANT TOUR

Evening:
Dinner—Topic, "Transportation by Pipeline"
AIIE BOARD OF TRUSTEES MEETING

FRIDAY, MAY 7

Morning:
TECHNICAL SESSION #5—LOOKING TO THE FUTURE
Topics—Dimensional Motion Times (DMT System)
—Tomorrow's Uses of 3D-Layout Design
—Automated Industries of Tomorrow

Afternoon:
Lunch—Topic, "The Story of What's Old"
AIIE ANNUAL BUSINESS MEETING—1st Session

Evening:
INSTALLATION OF OFFICERS BANQUET
Annual Dance (Informal)

SATURDAY, MAY 8

Morning:
AIIE ANNUAL BUSINESS MEETING—2nd Session
Kentucky Famed Churchill Downs Engineering Event to include lunch

An appropriate program is being arranged for the ladies.

For Reservations Write To:
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Louisville 2, Kentucky
National Convention Chairman:
STEPHEN A. DERRY
Host Chapter Chairman:
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